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(54) **FLUID CONTAINER APPARATUS HAVING SUPPORT ELEMENTS FOR SUPPORTING APPARATUS COMPONENTS**

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(51) **Int. Cl.**
B65B 1/30 (2006.01)

(52) **U.S. Cl.** **137/587**; 137/377

(58) **Field of Classification Search** 137/377, 137/376, 583, 587, 588, 343, 356, 382; 222/183; 165/81, 82
See application file for complete search history.

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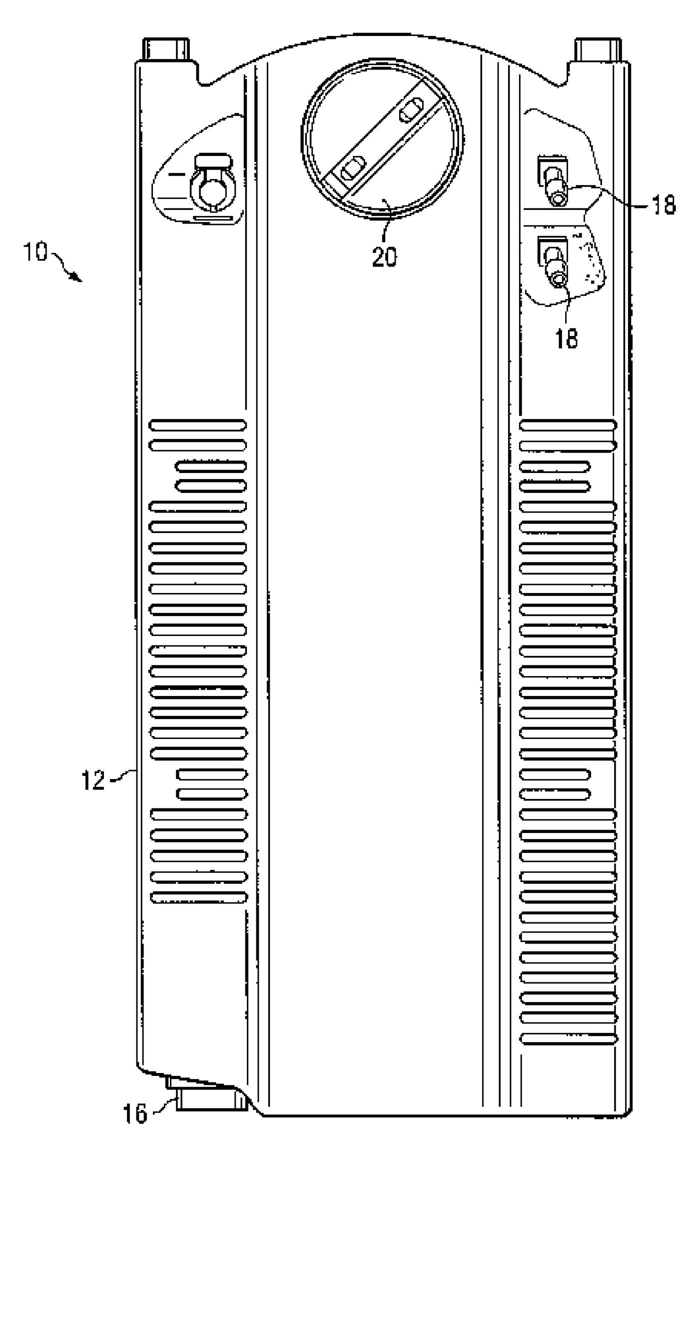
Primary Examiner—John Fox

(57) **ABSTRACT**

A fluid storage and delivery apparatus may include a fluid container, a first apparatus component, and a housing. One or more support members may be coupled to the housing and configured to secure the first apparatus component physically separate from the fluid container. The first apparatus component may be indirectly coupled to the fluid container by one or more coupling members at least partially defining a fluid passageway between the first apparatus component and the fluid container.

21 Claims, 14 Drawing Sheets



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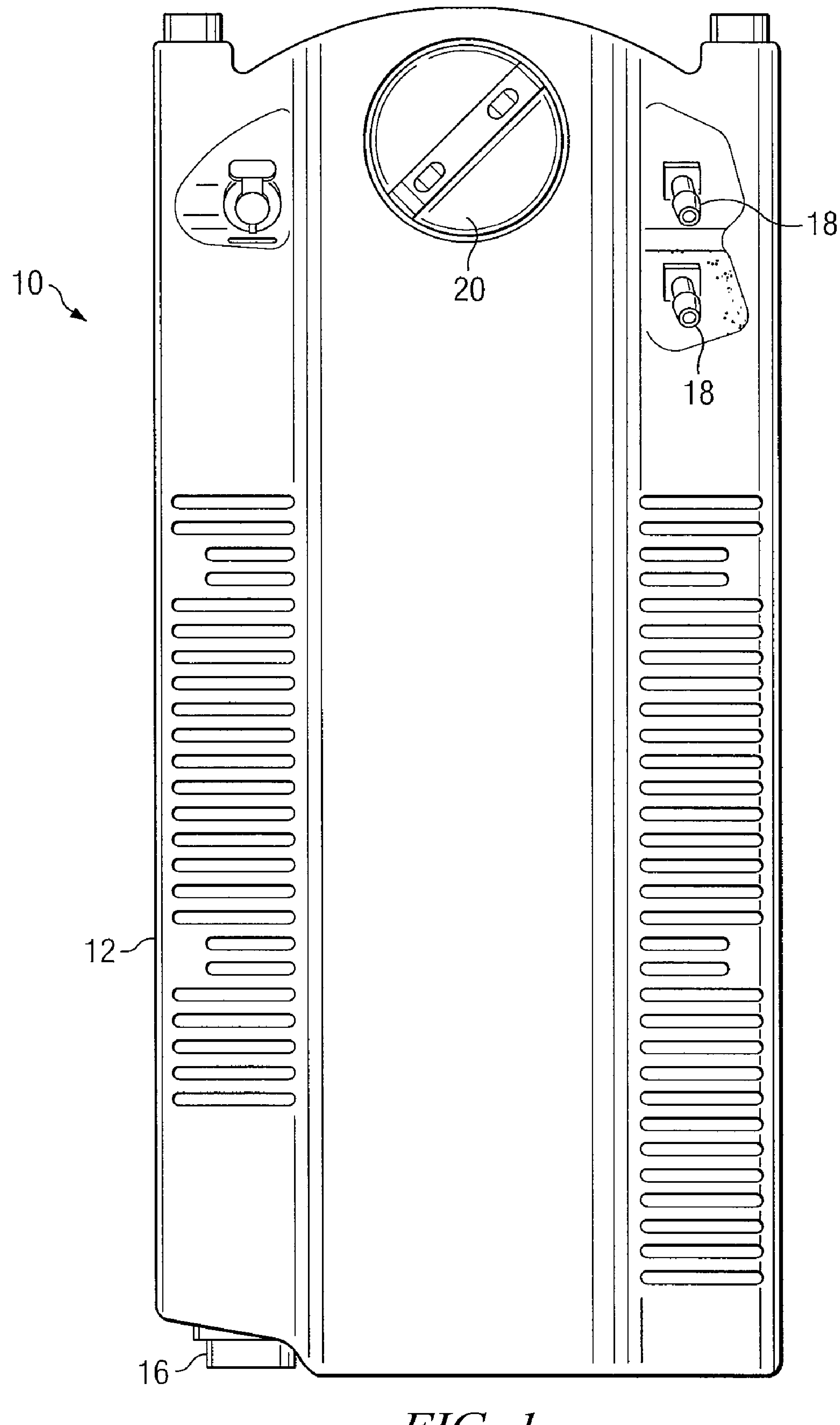

FIG. 1

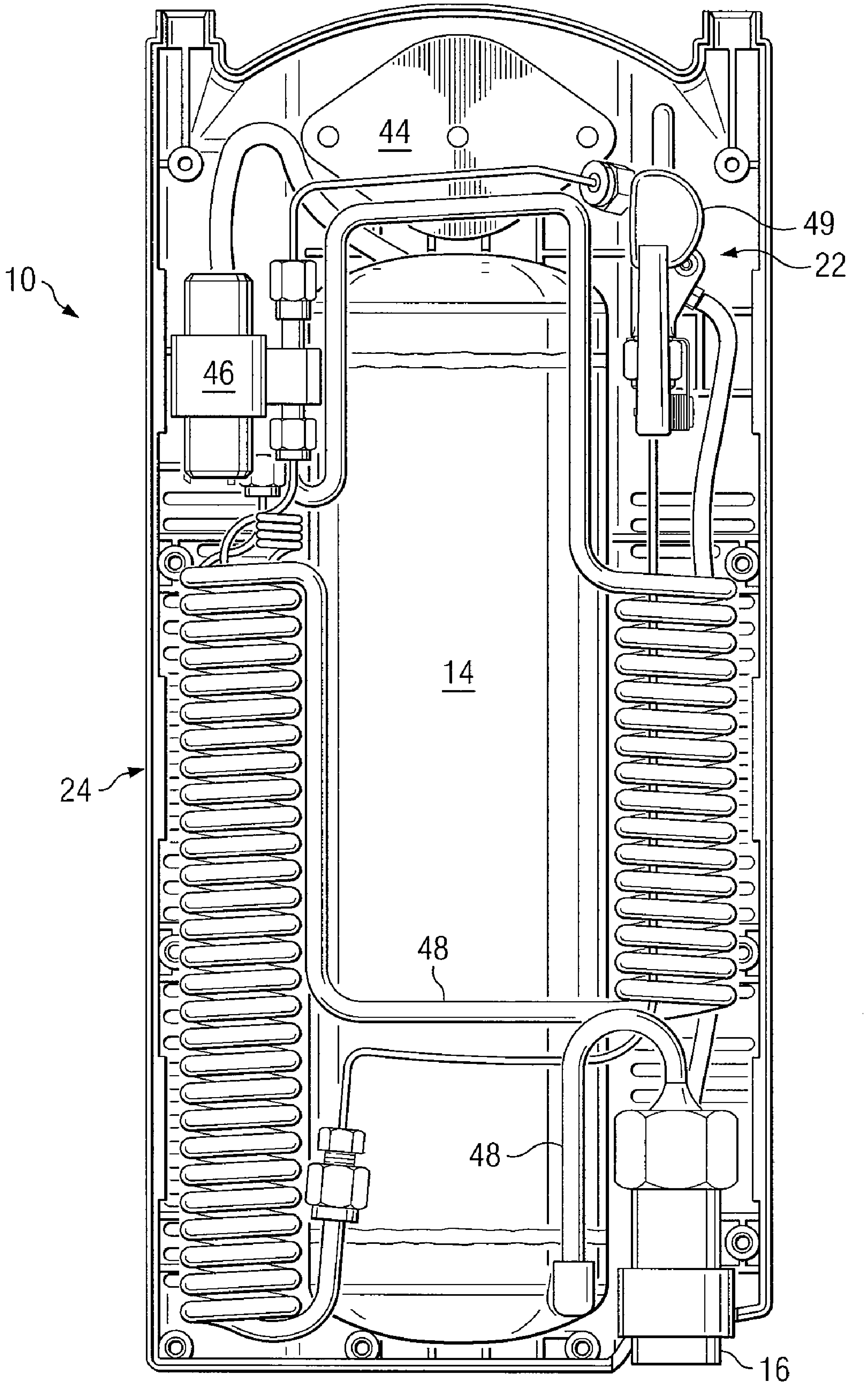

FIG. 2

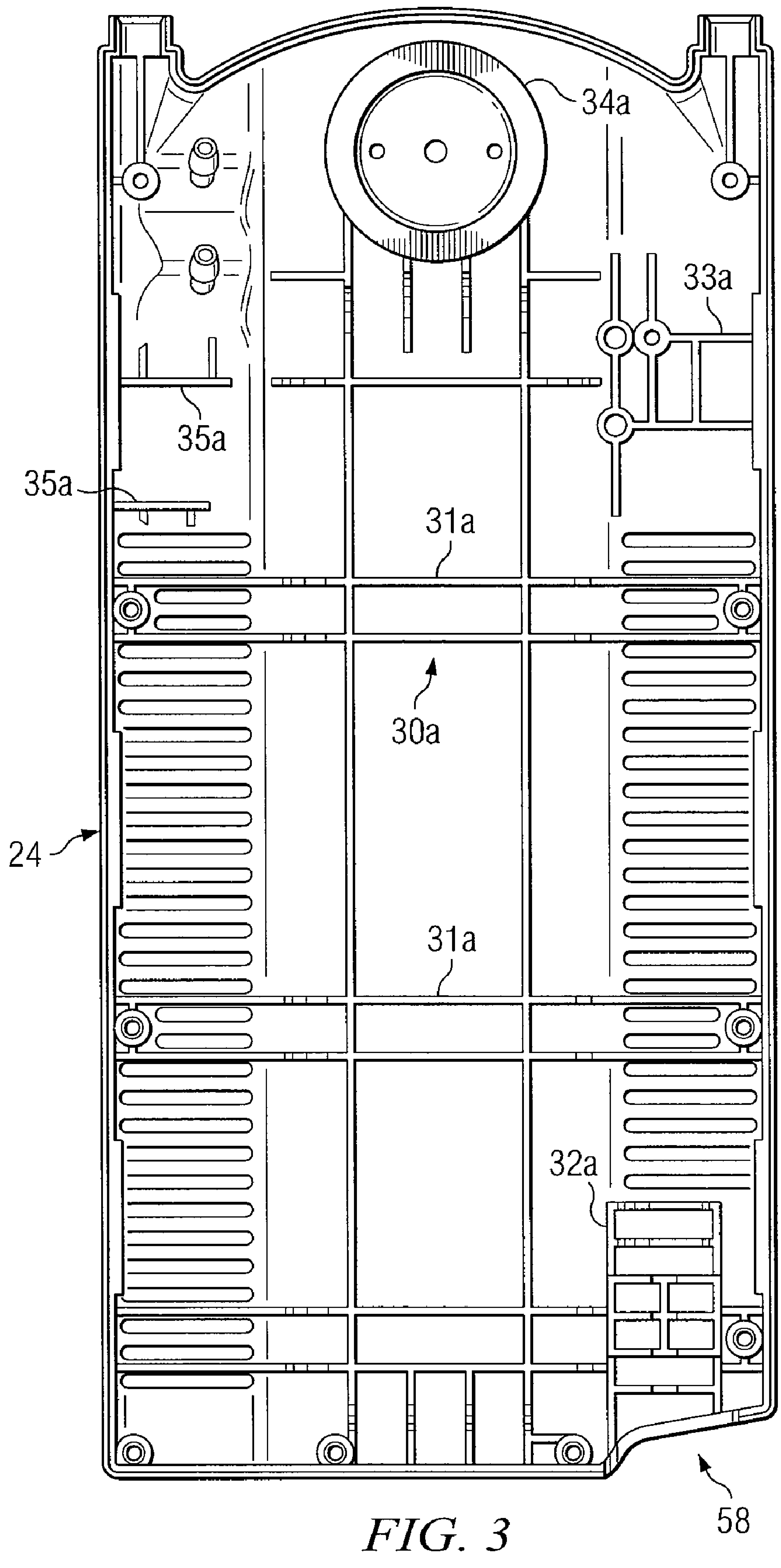

FIG. 3

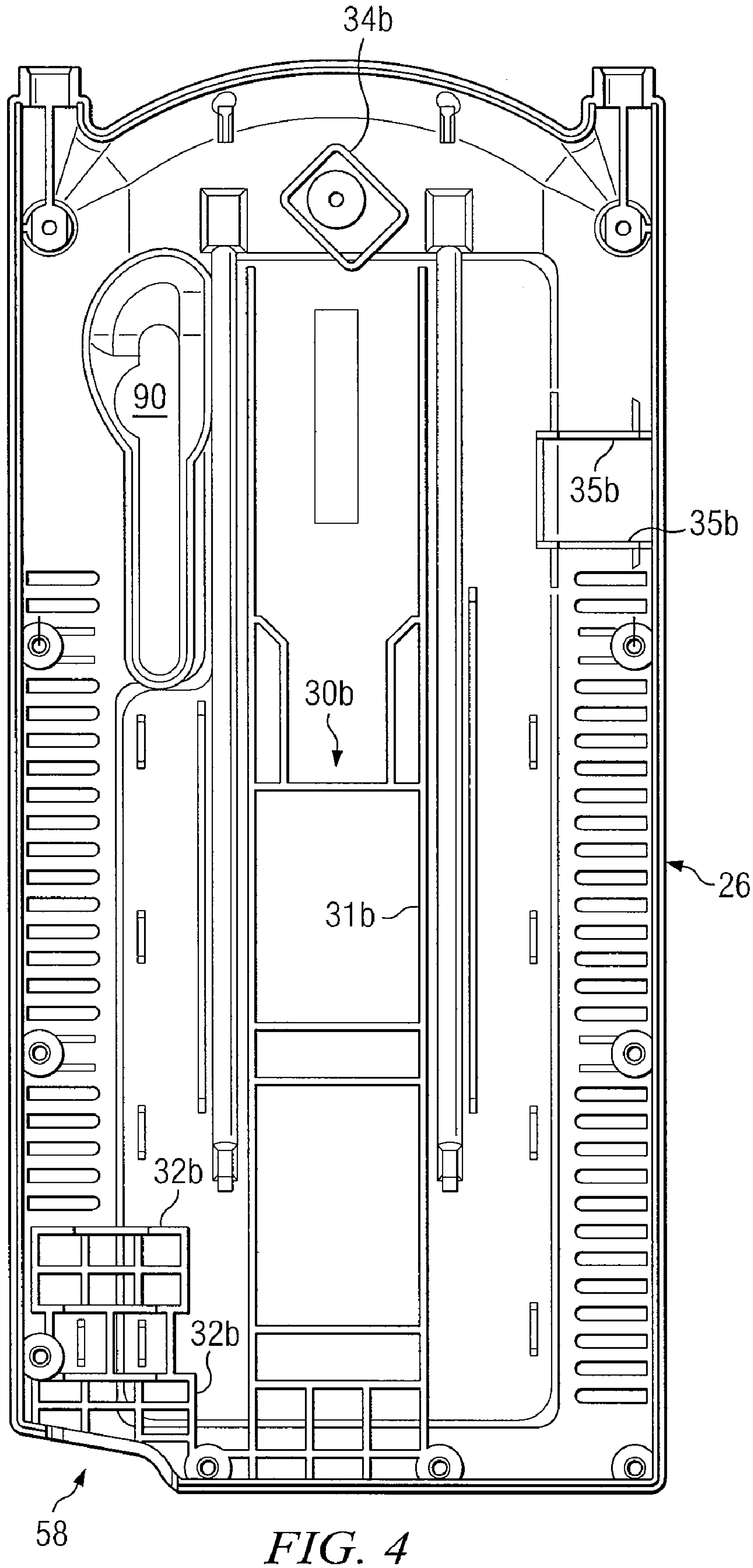

FIG. 4

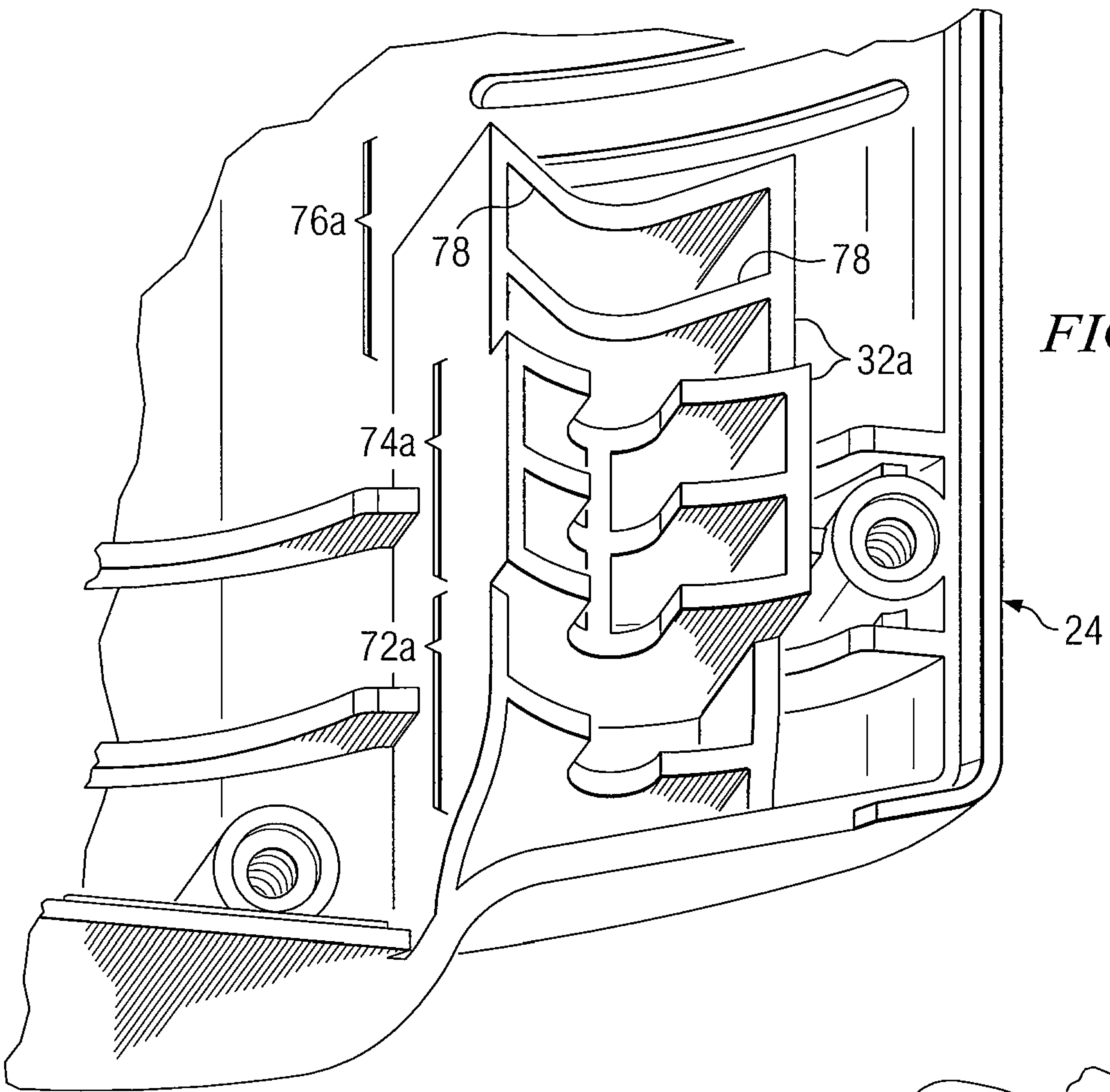

FIG. 5

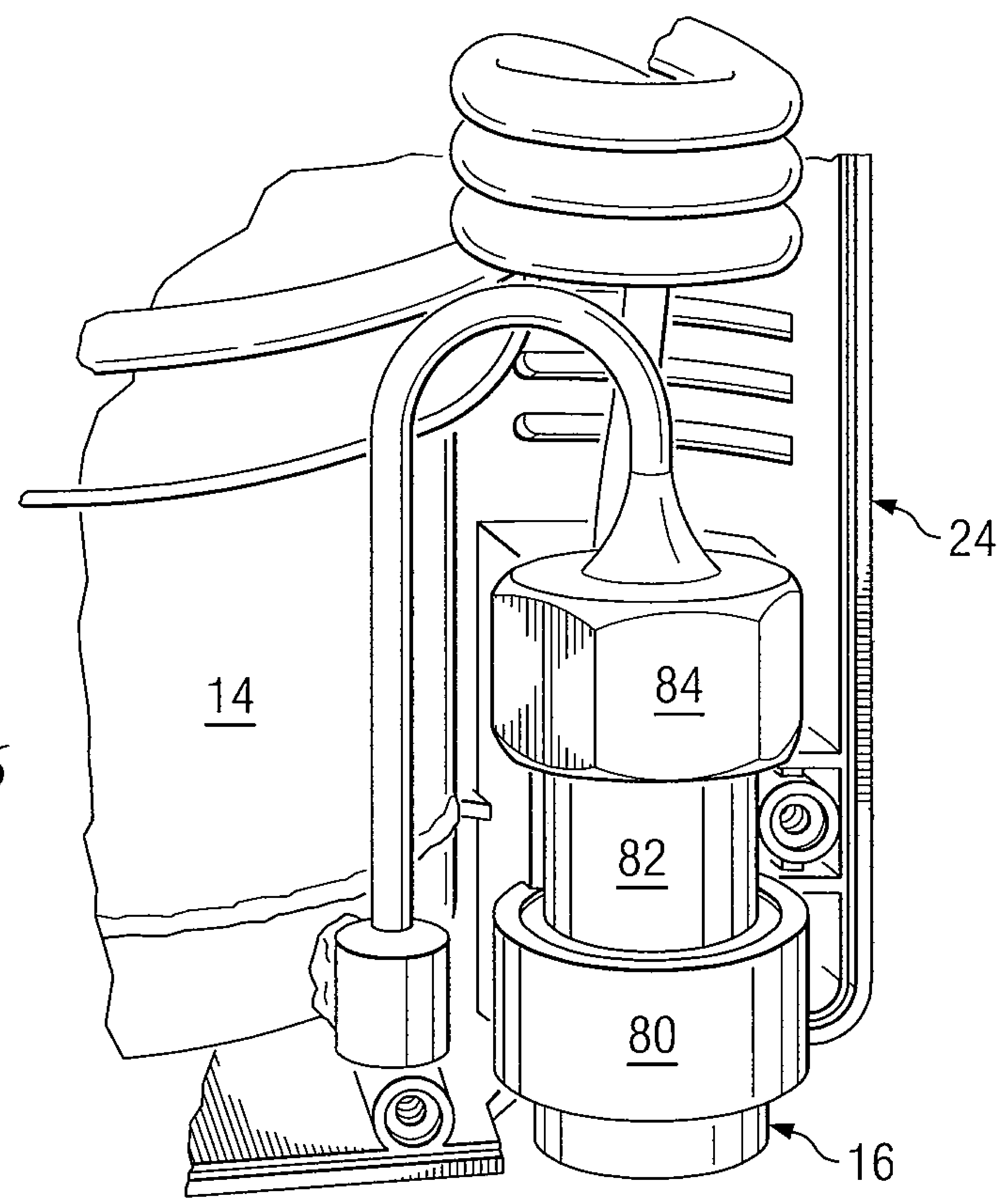

FIG. 6

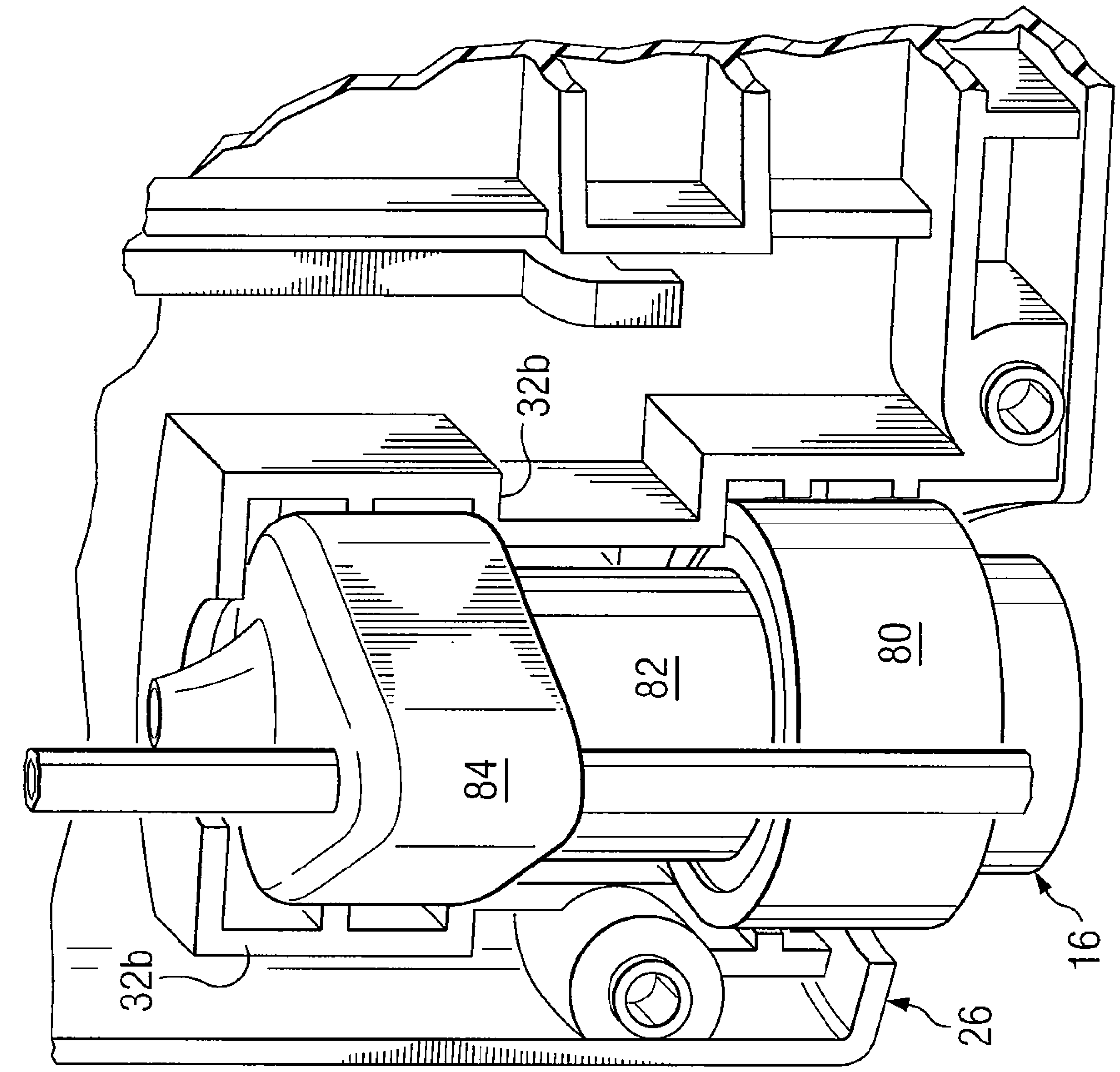

FIG. 8

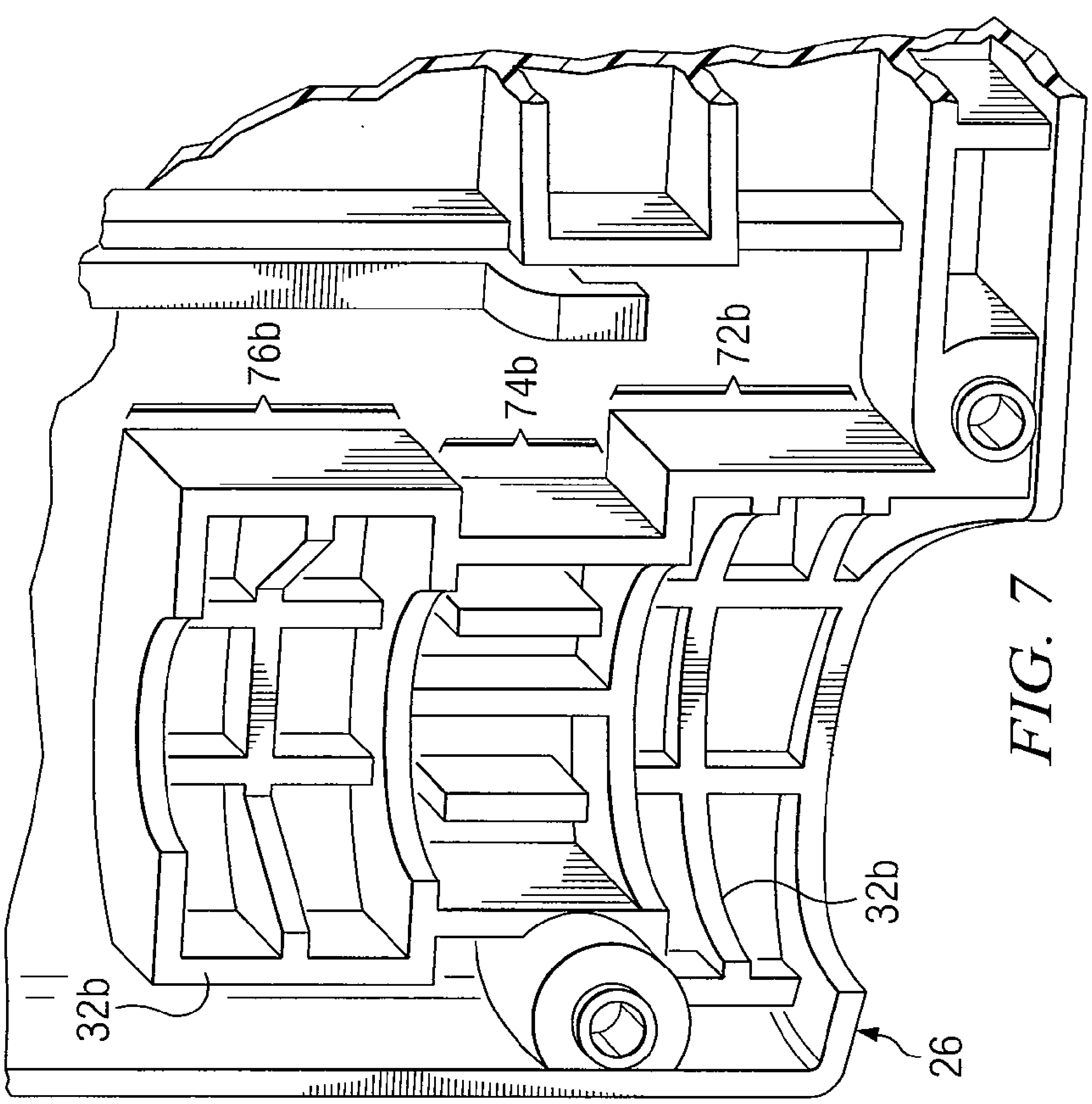

FIG. 7

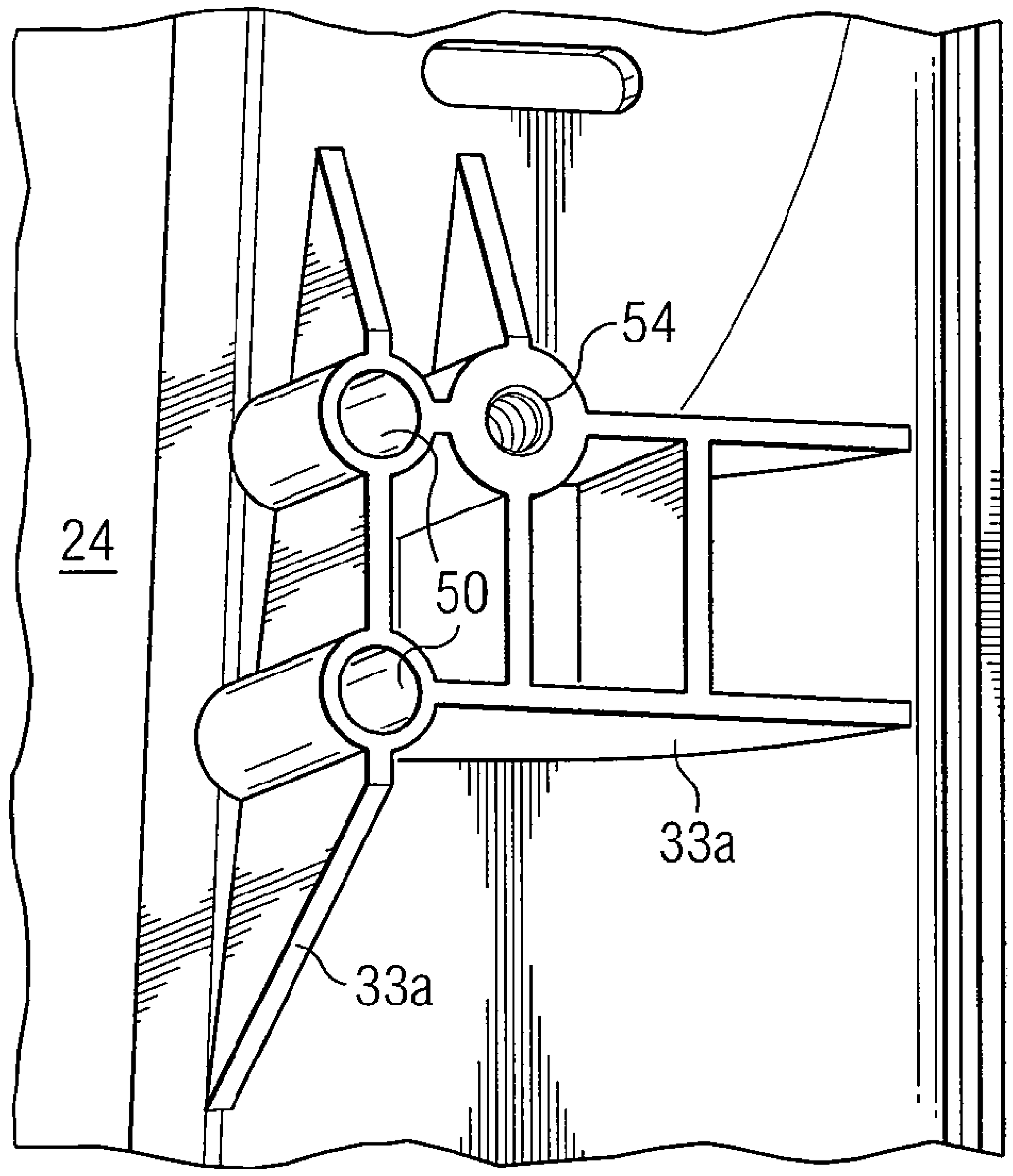

FIG. 9

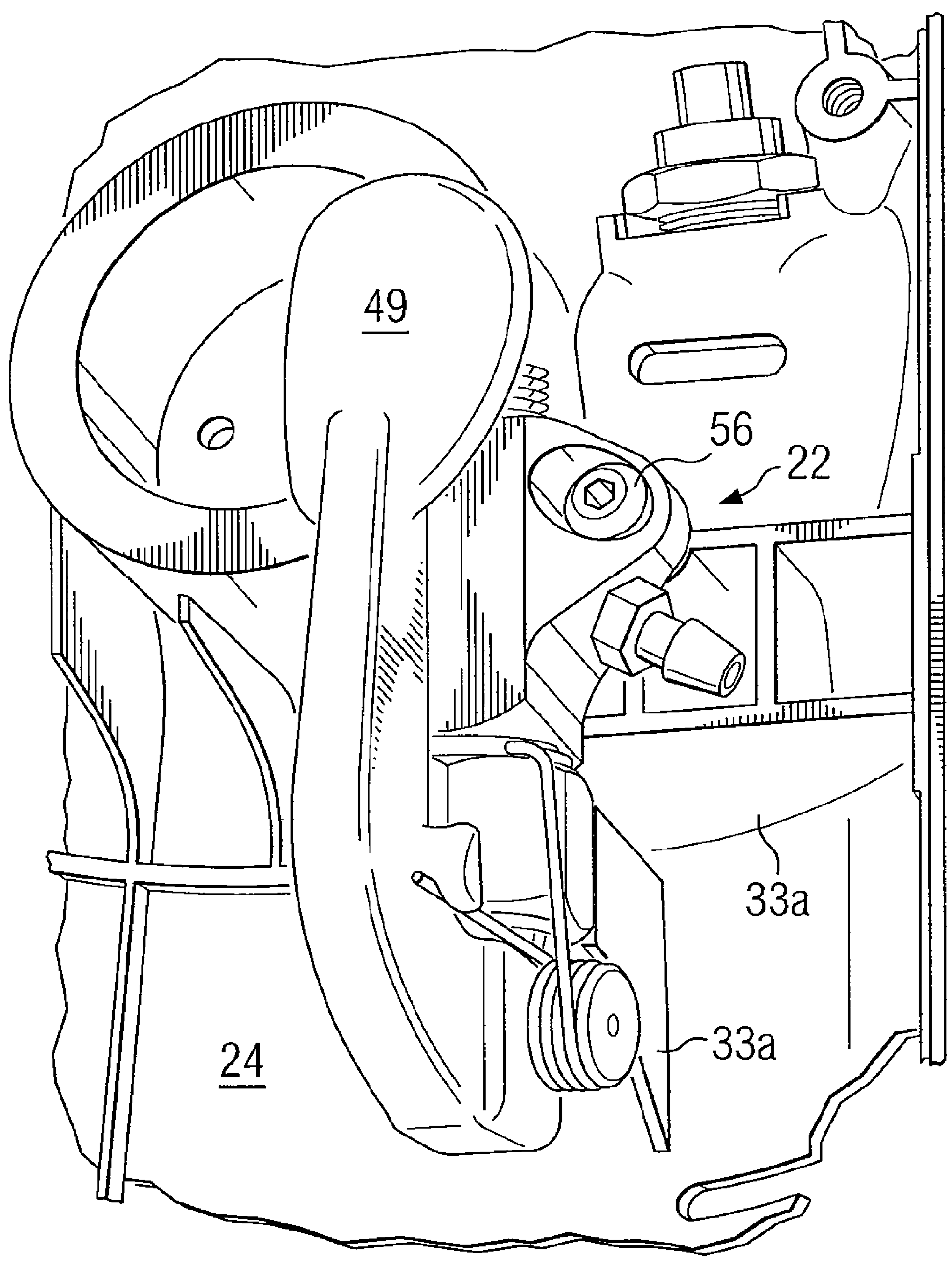

FIG. 10

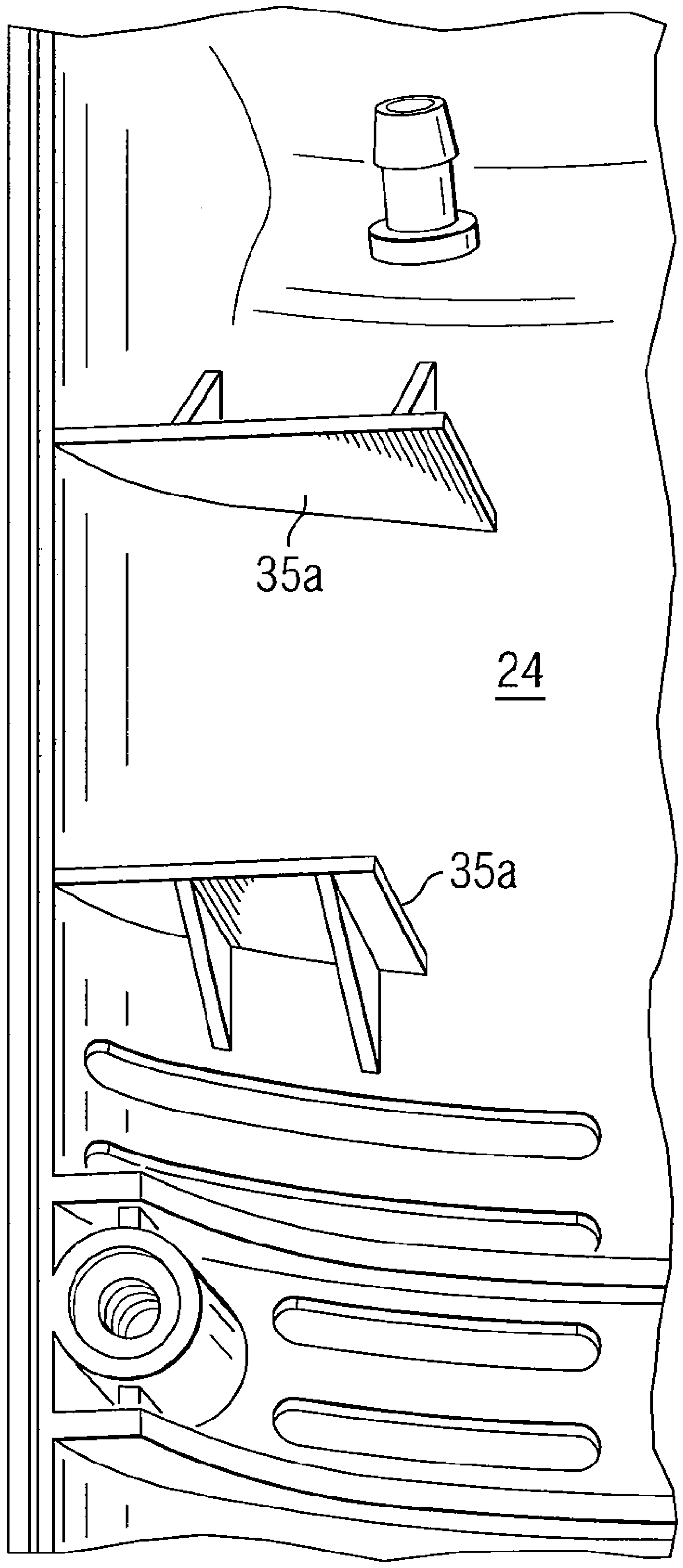

FIG. 11

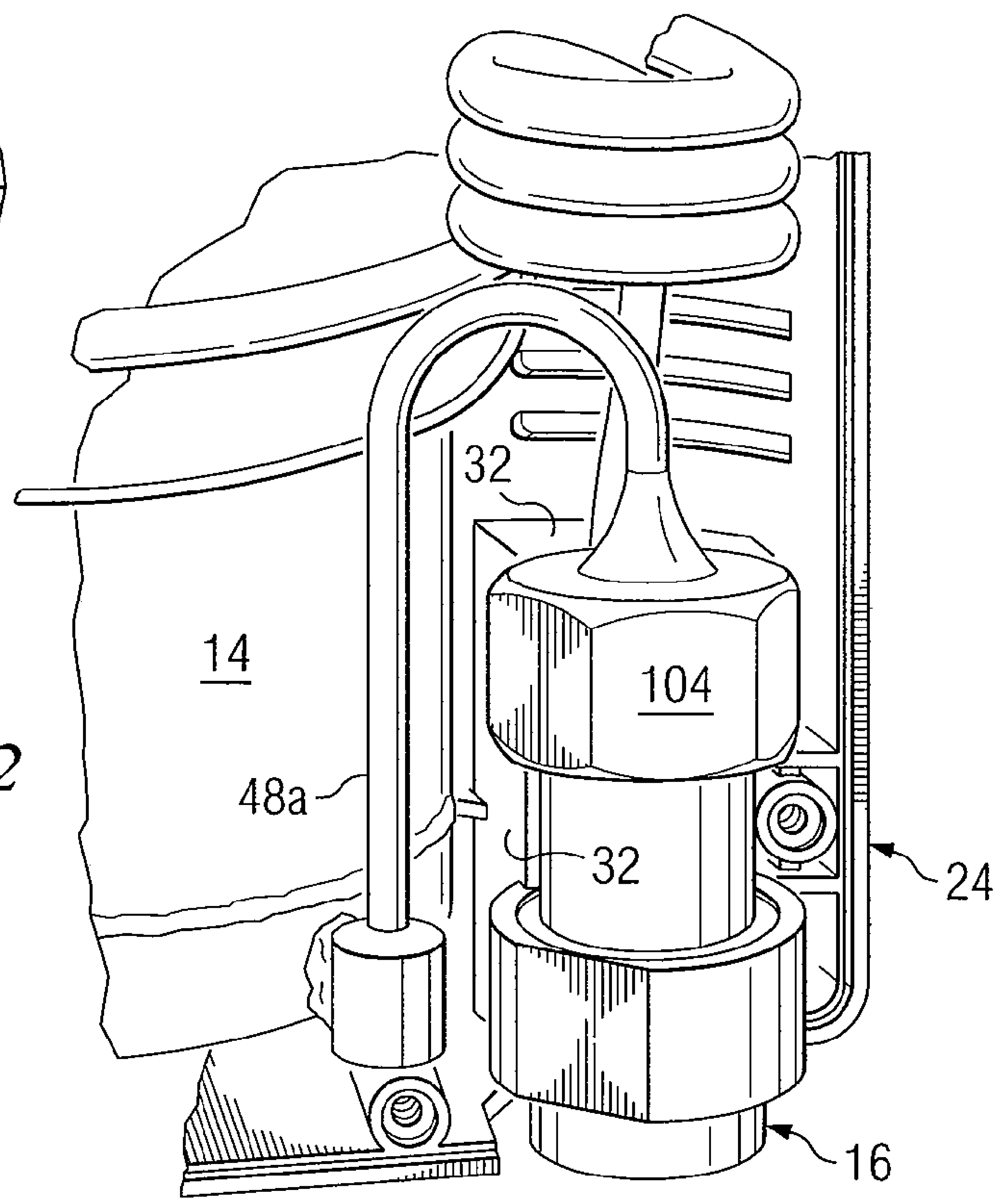

FIG. 12

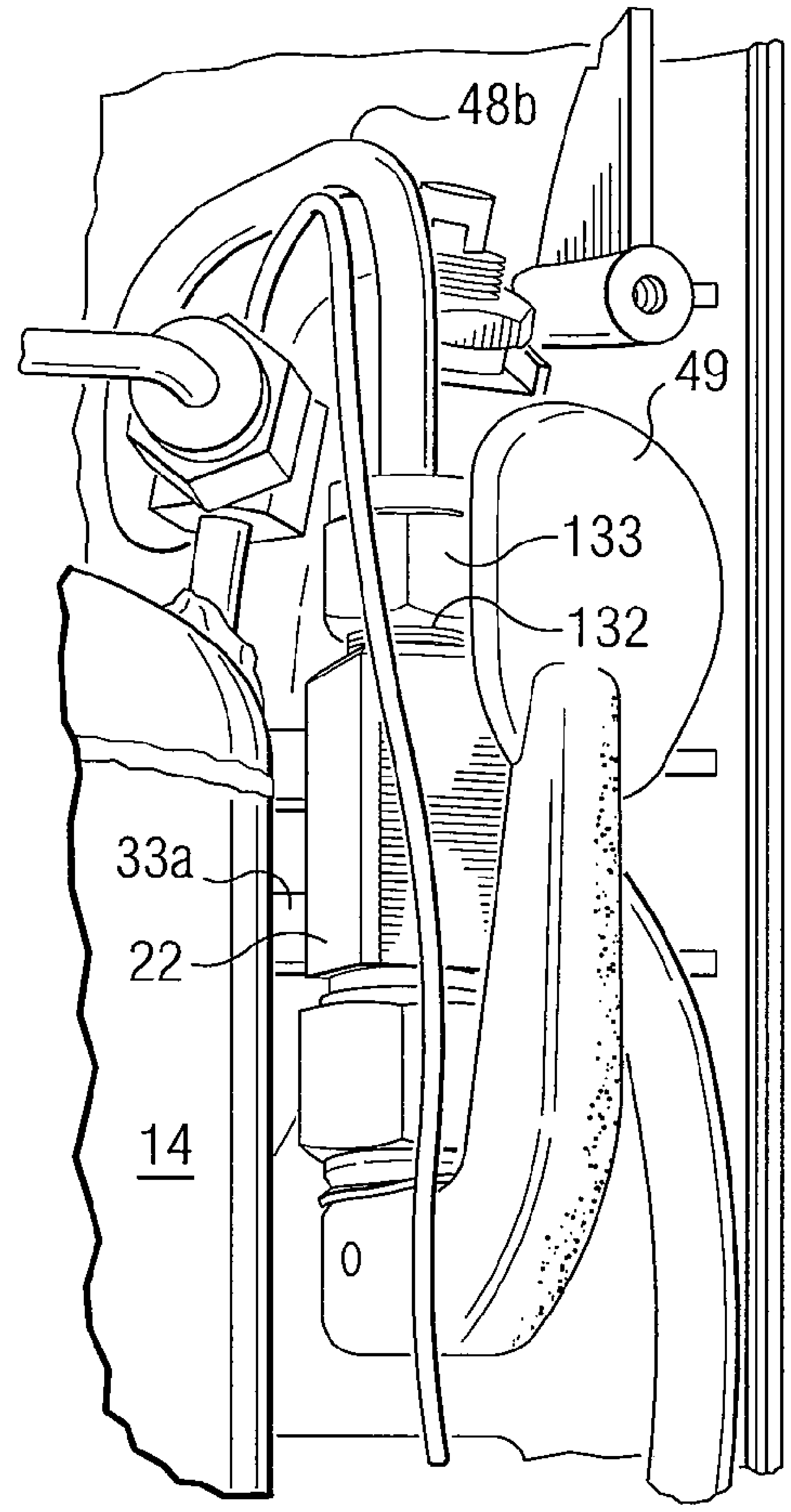

FIG. 13

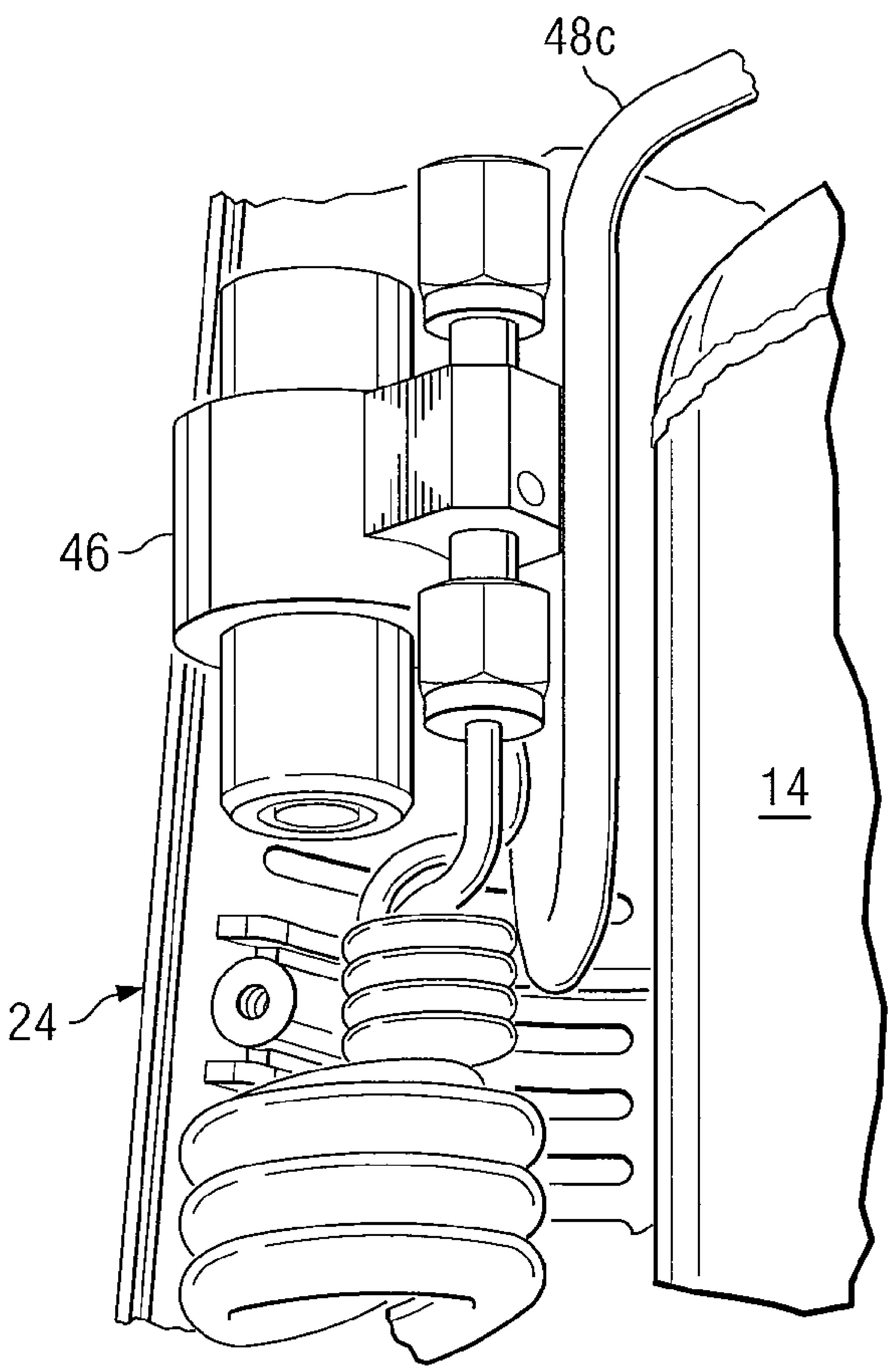

FIG. 14

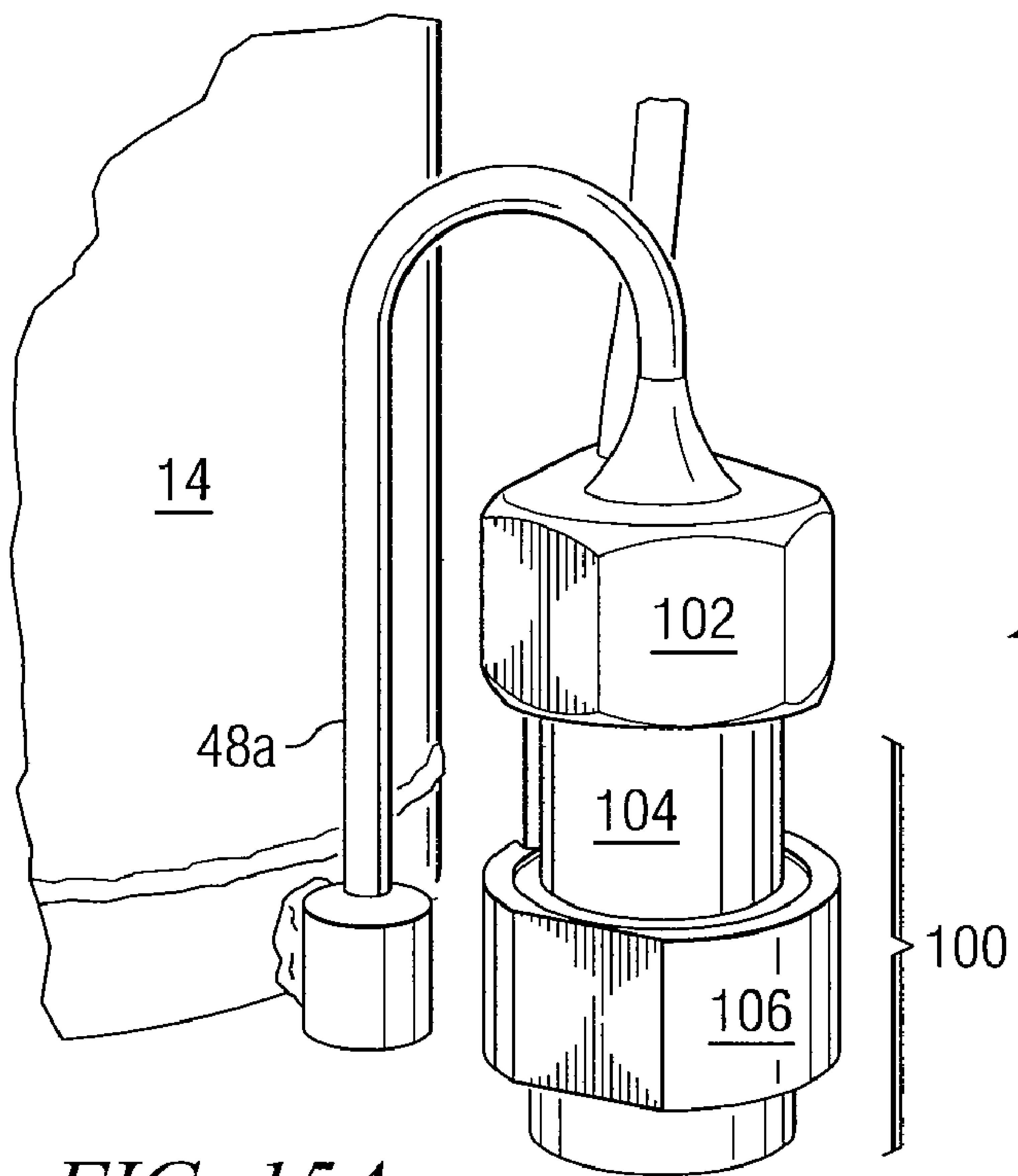

FIG. 15A

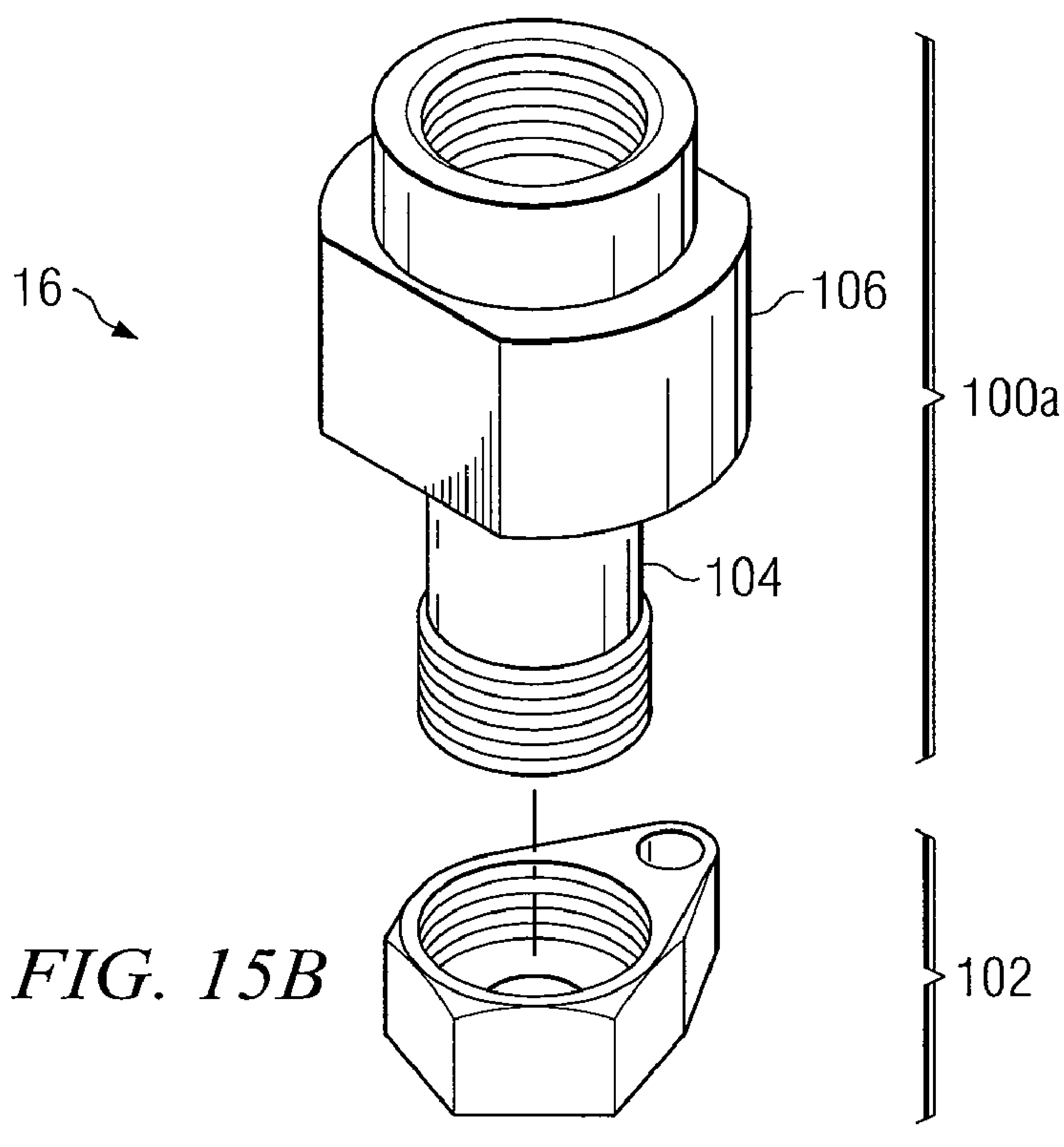

FIG. 15B

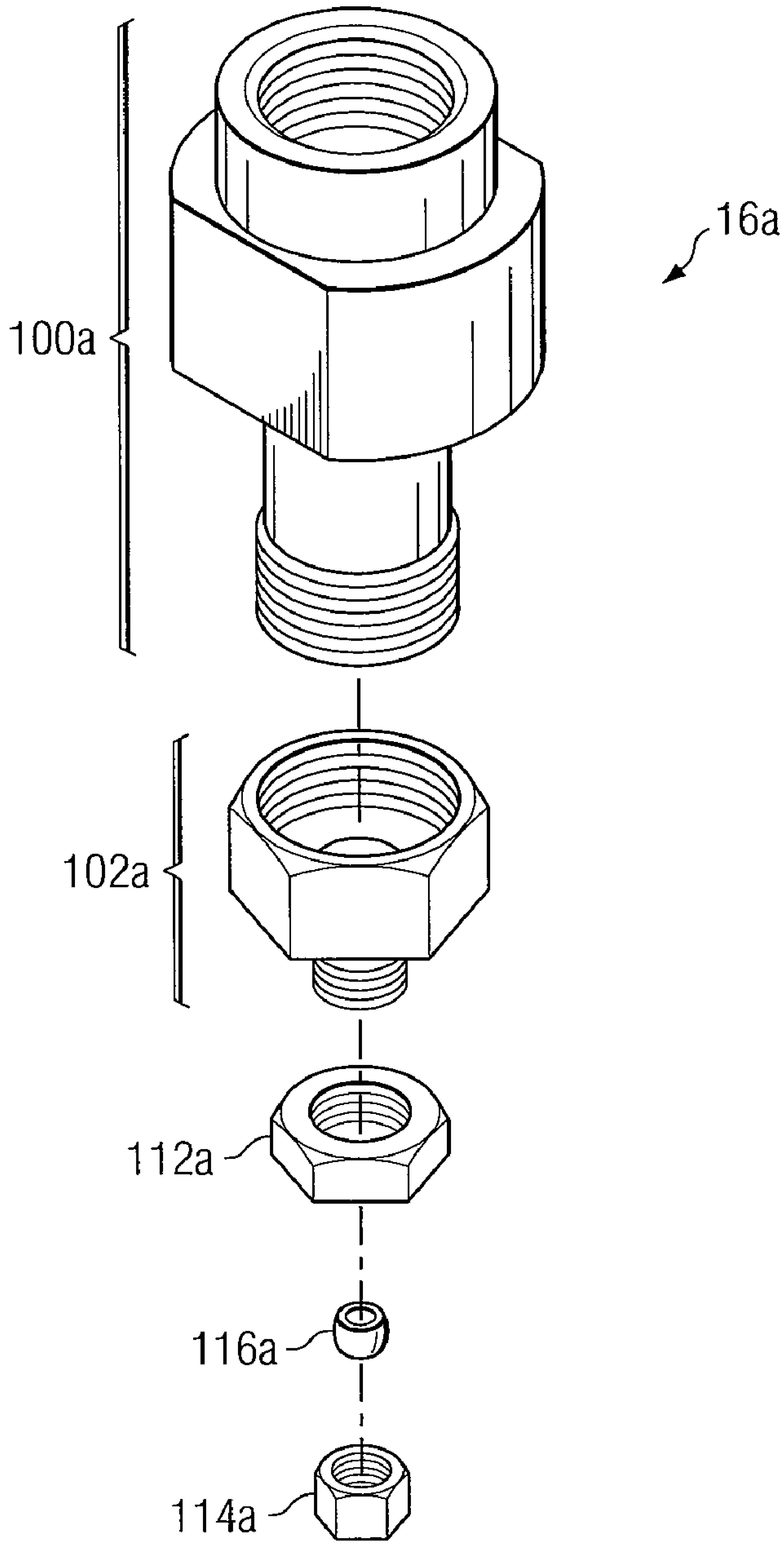

FIG. 16

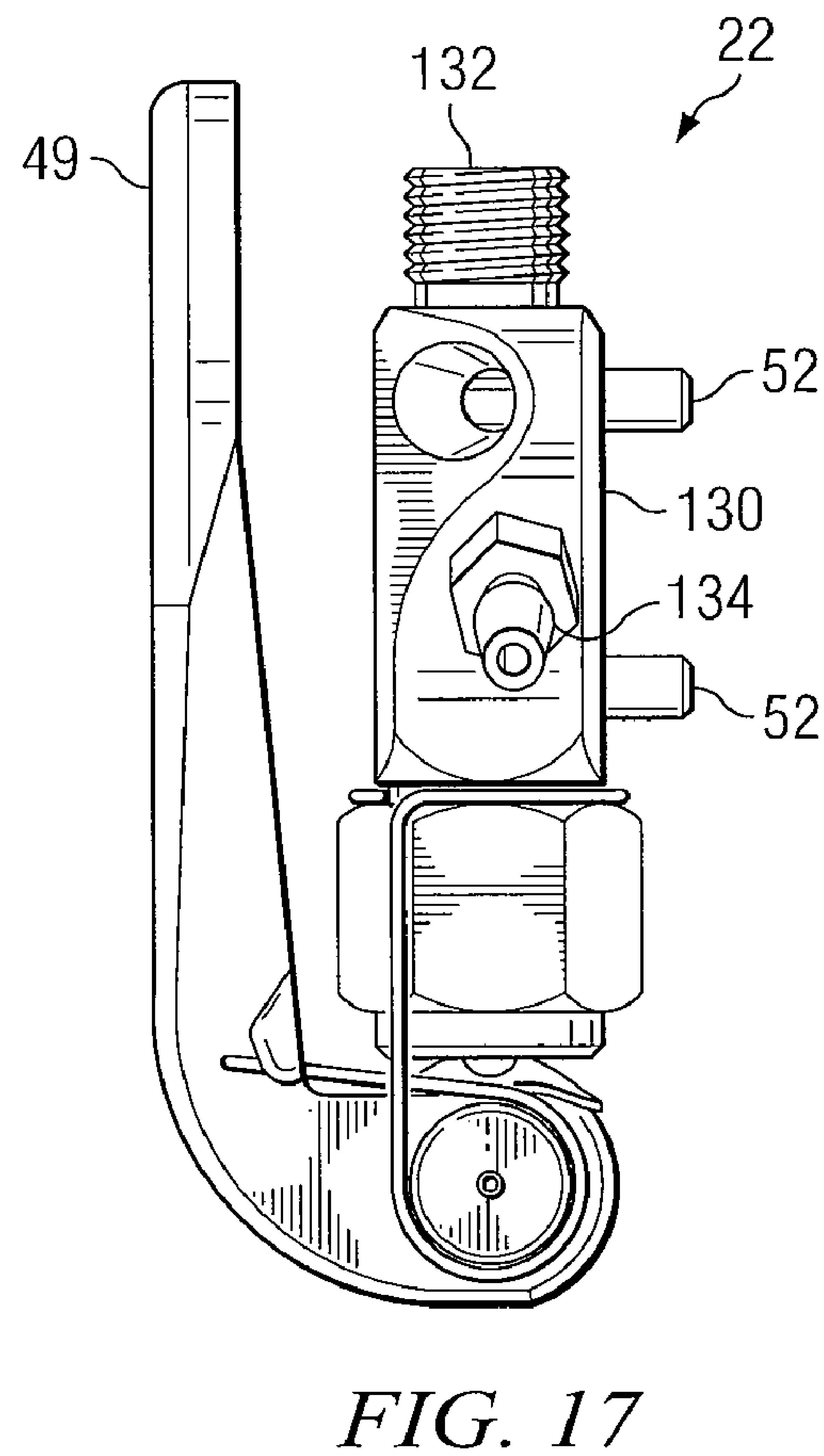

FIG. 17

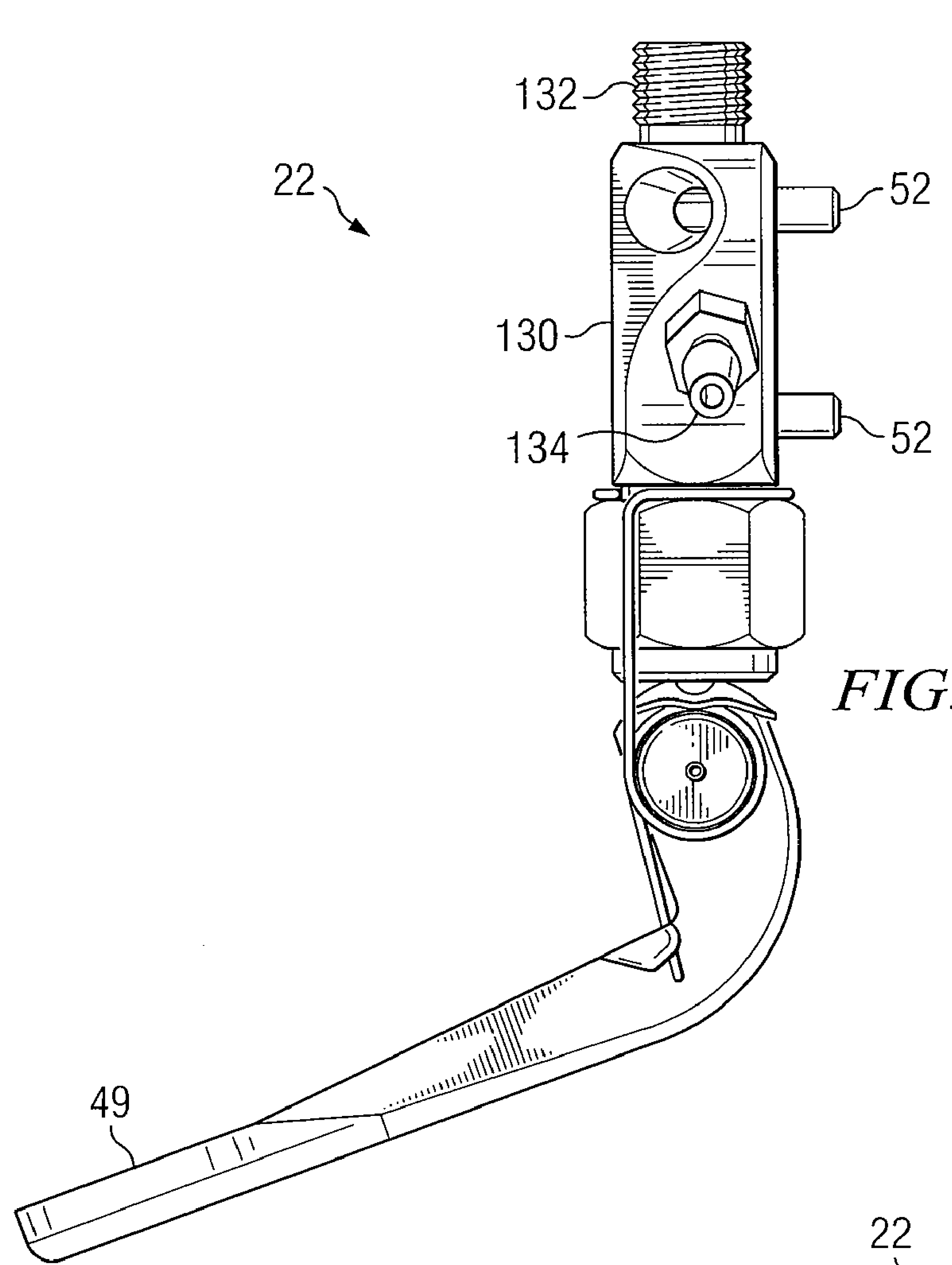

FIG. 18

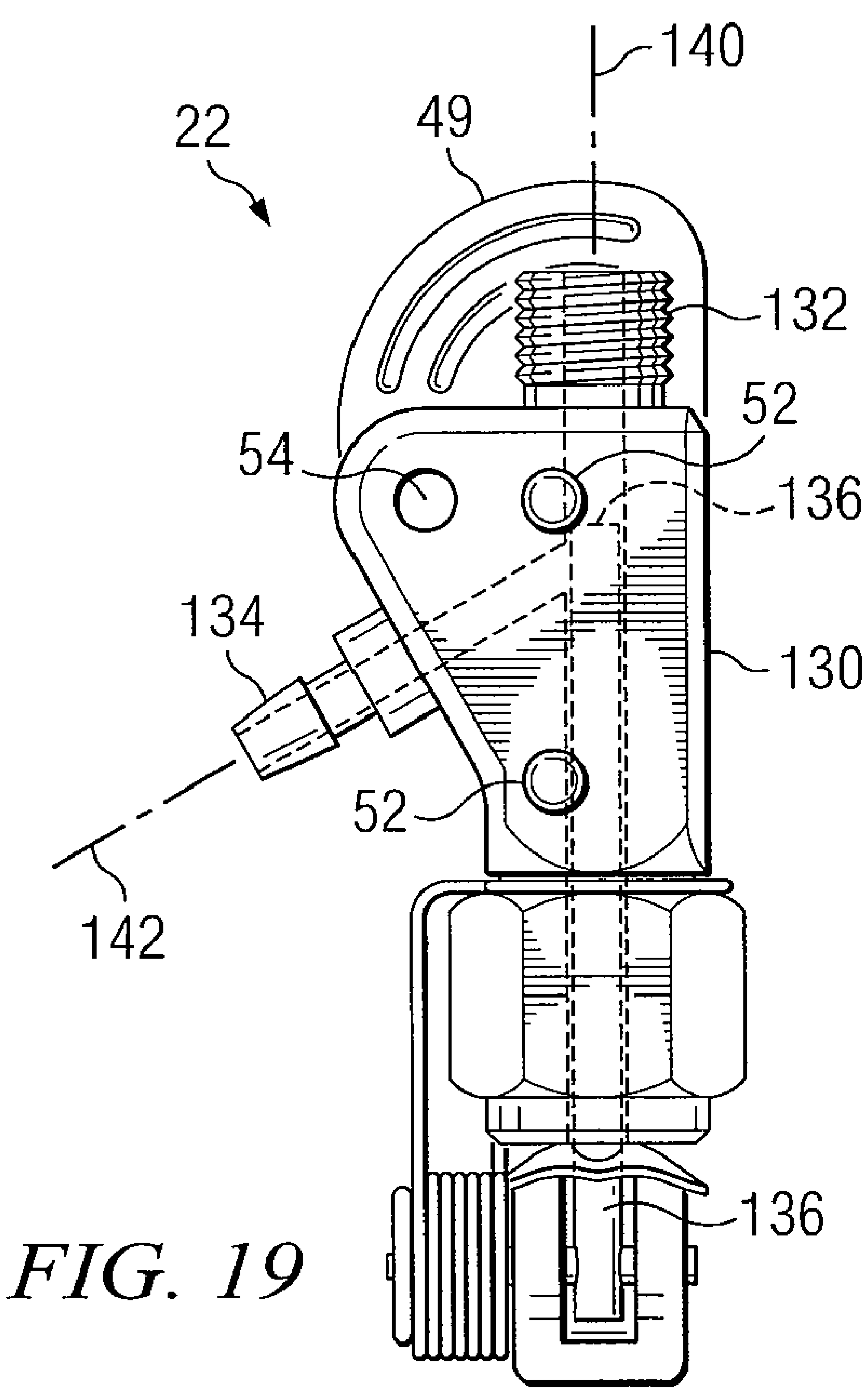

FIG. 19

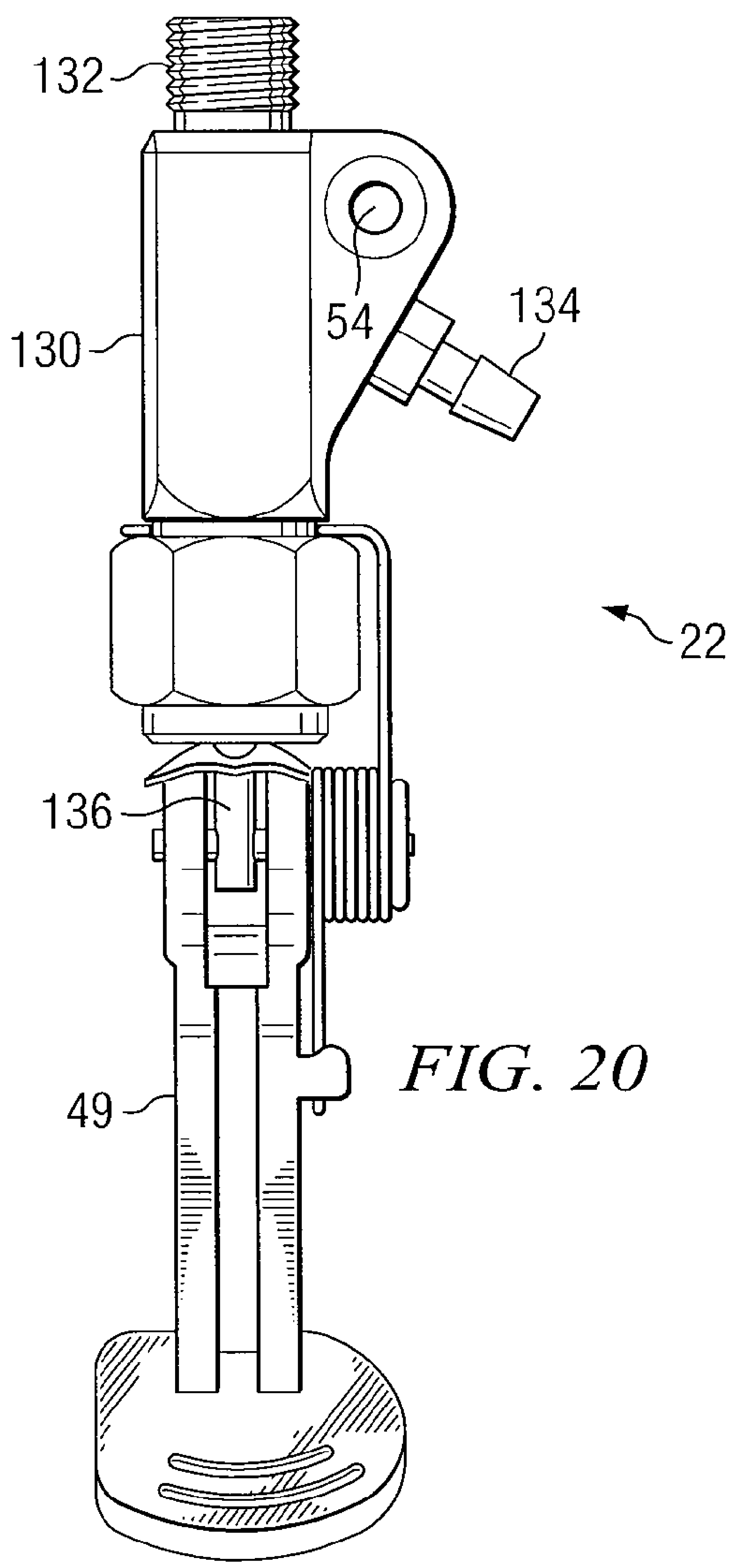

FIG. 20

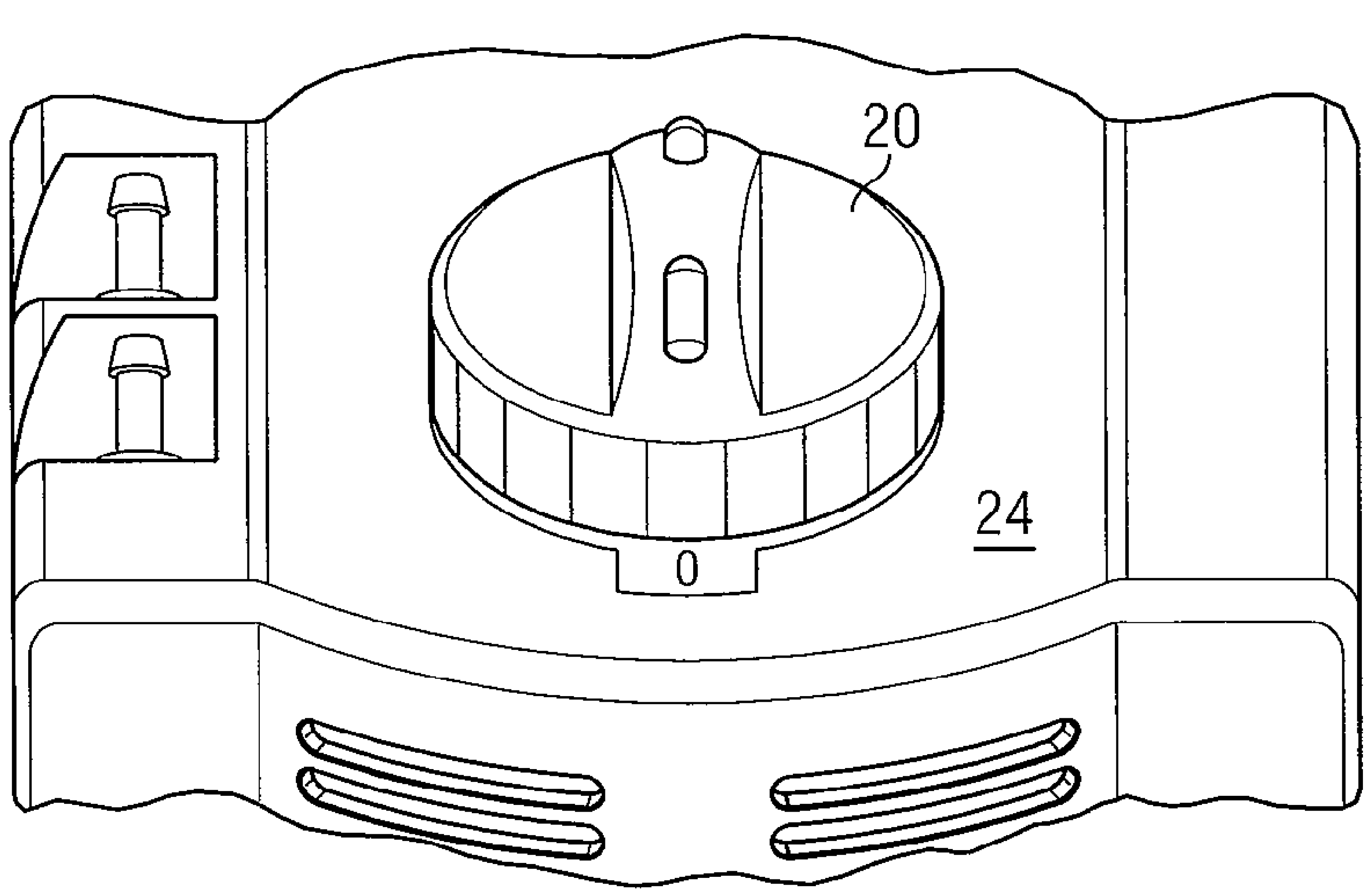

FIG. 21

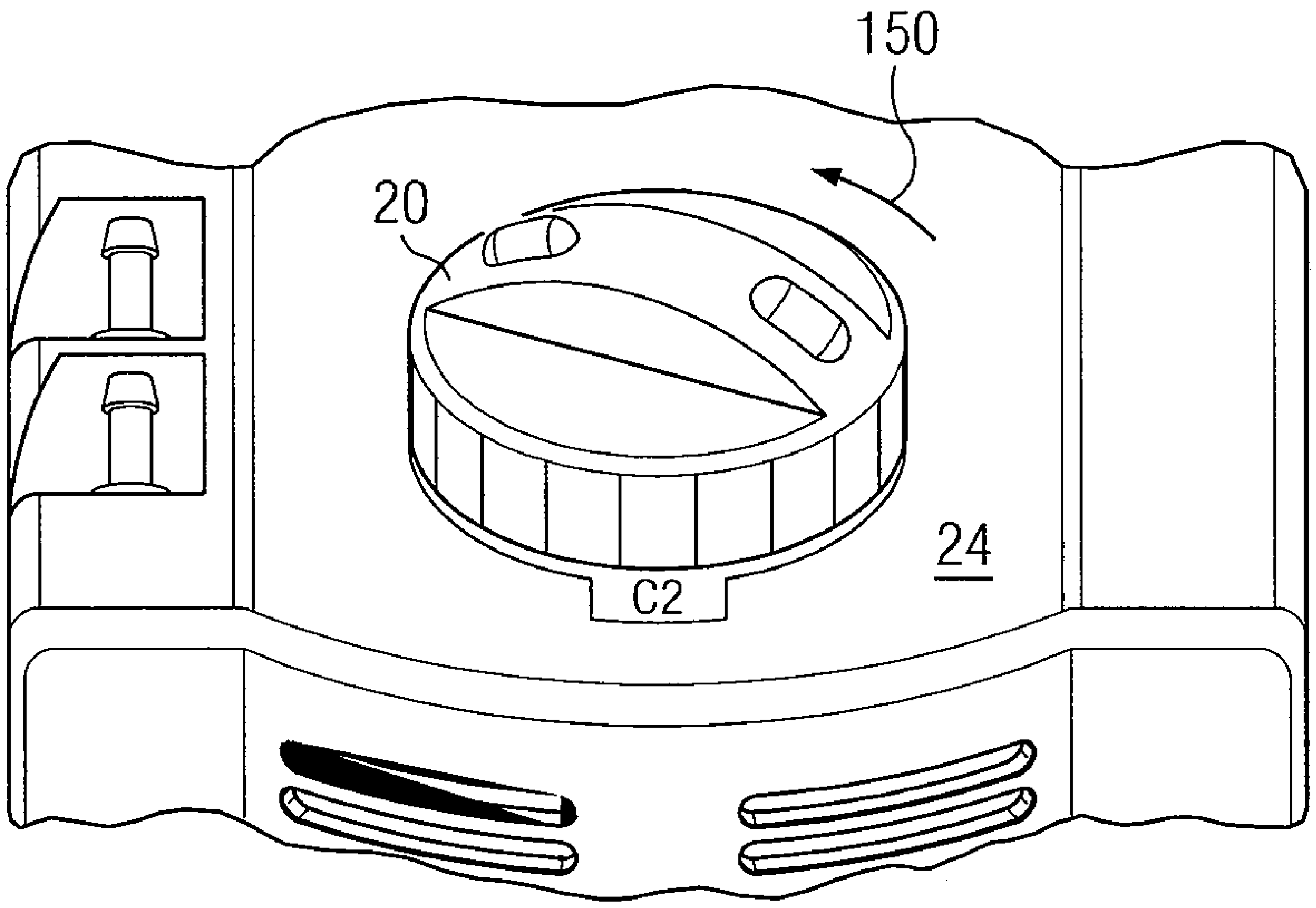

FIG. 22

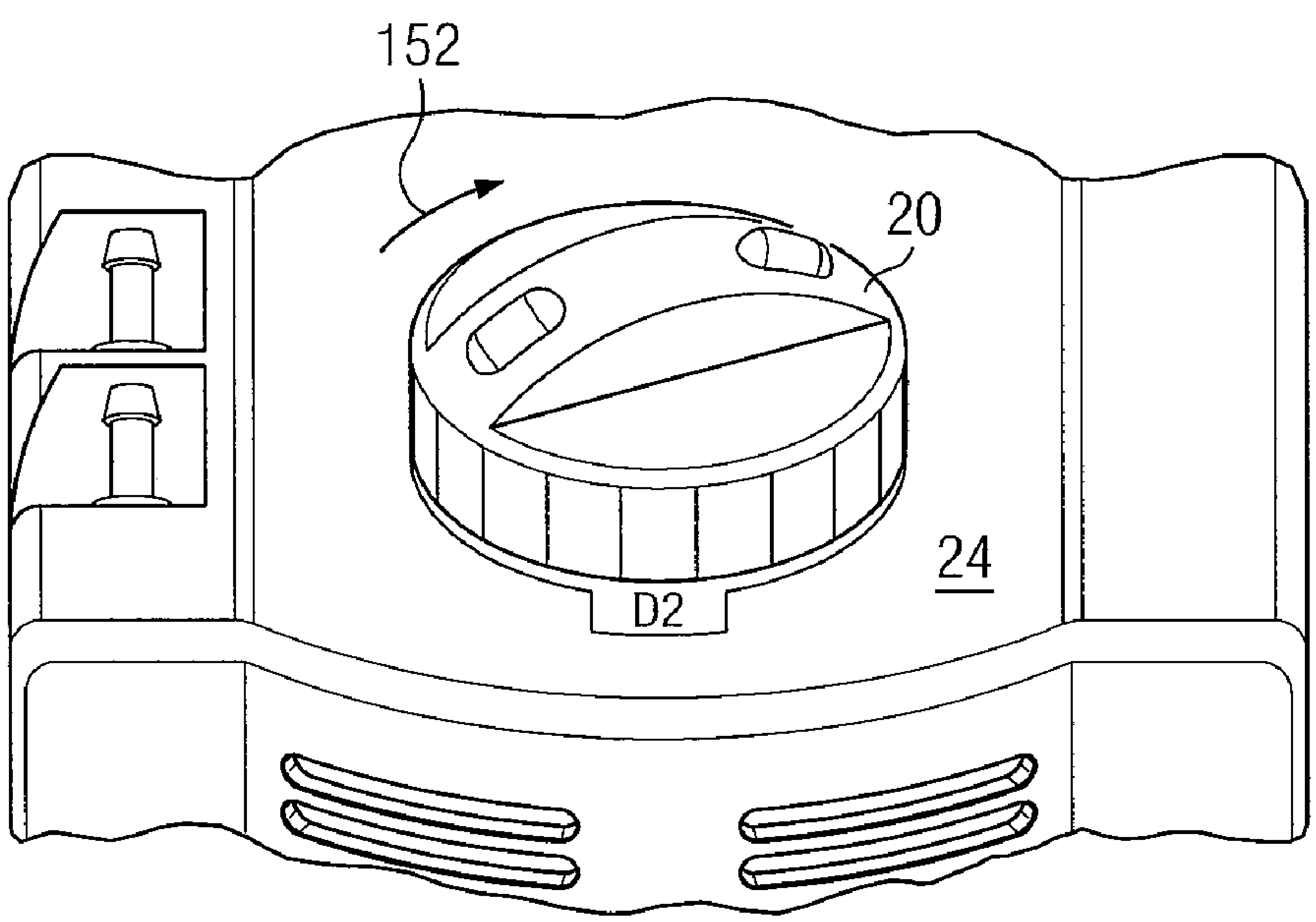

FIG. 23

FLUID CONTAINER APPARATUS HAVING SUPPORT ELEMENTS FOR SUPPORTING APPARATUS COMPONENTS

RELATED APPLICATION

This application is a continuation of co-pending International Application No. PCT/US2005/027976 filed Aug. 6, 2005, which designates the United States, and claims priority to and the benefit of U.S. Provisional Application No. 60/599,020, filed Aug. 6, 2004, the contents of which are hereby incorporated by reference in their entirety.

TECHNICAL FIELD

The present disclosure is related generally to fluid container apparatuses, and more particularly to a fluid container apparatus having support elements for supporting, aligning, and/or securing apparatus components.

BACKGROUND

Therapeutic oxygen is commonly provided to subjects in order to treat a variety of medical conditions, including various conditions in which the subject suffers from a loss of lung capacity. Examples of medical conditions that may result in a loss of lung capacity include chronic obstructive pulmonary disease (COPD) such as asthma, emphysema, etc., as well as cystic fibrosis, lung cancer, lung injuries, and cardiovascular diseases. Pure or substantially pure oxygen may be delivered to the subject to treat the relevant condition. Inhaling the delivered therapeutic oxygen may help the subject achieve and/or maintain an adequate level of oxygen in his or her bloodstream.

Portable therapeutic oxygen has conventionally been provided in two ways. The first approach involves storing compressed oxygen gas in a pressure container and delivering the gas through a pressure regulator and through a hose, lumen, cannula or other passage to the subject's breathing orifices (e.g., nostrils). In some instances, the container may be wheeled such that the subject may be at least somewhat mobile. However, portable compressed gaseous oxygen systems suffer from various disadvantages, such as the fact that a full portable container typically lasts a relatively short period of time, and the fact that the system may be relatively heavy and obtrusive, which may limit the subject's mobility.

The second approach involves storing liquid oxygen (or "LOX") in a portable container and delivering gaseous oxygen evaporated from the liquid oxygen to the subject through a hose, lumen, cannula or other passage to the subject's breathing orifices (e.g., nostrils). Such an apparatus for storing liquid oxygen and/or delivering evaporated gaseous oxygen may be referred to as an "LOX apparatus." Although oxygen is typically a gas at standard atmospheric conditions, it may be maintained as a liquid at very low temperatures, which substantially reduces the volume of the oxygen, thus substantially reducing the required size of the LOX apparatus as compared to compressed gaseous oxygen systems. LOX apparatuses typically include a vacuum-insulated container or a partially vacuum-insulated container for storing and maintaining the LOX at a very low temperature.

As compared to compressed gaseous oxygen systems, an LOX apparatus enjoys a longer usable charge for a given size or weight. Accordingly, the LOX apparatus can be much smaller than known compressed gaseous oxygen systems and can provide the same or longer duration of useable charge, while being lighter and/or less obtrusive.

In order to fill, or "charge," the vacuum-insulated container of the LOX apparatus with LOX, the LOX apparatus may include a fill port in fluid communication with the container. The fill port may be configured to temporarily engage or connect to a LOX reservoir or some other source of LOX. The fill port may facilitate the transfer of LOX from the LOX reservoir to the container of the LOX apparatus. The fill port typically undergoes stress loading during filling due to the contact with the LOX reservoir and associated forces and/or pressures. To engage the fill port with the LOX reservoir, a user may need to apply pressure to the fill port to activate the connection.

The fill port of an LOX apparatus may be physically attached to the LOX container. For example, the fill port may be attached to the container by a flange that is mechanically fastened to the fill port (e.g., using a nut and screw) and mechanically fastened (e.g., using a worm-drive clamp) or welded to the container. This arrangement may transfer some or all of the physical stresses experienced by the fill port (e.g., during filling) from the fill port to the container. Whether the fill port is connected to the container via welding, braze, or mechanical fastener, the cyclical stress on the container may, especially over time, cause the vacuum shell or the container to be compromised or punctured. Similarly, the stresses transferred to the container may cause the container and its attached components to shift both horizontally, vertically and/or rotationally, which may cause undesirable load paths and/or stress points. These load paths and/or stress points may cause leakage within the LOX apparatus and/or failures of one or more of the LOX apparatus components. In addition, in situations in which flanges are welded to the container (for coupling one or more components to the container), the welding may cause a weld puncture and/or thin wall distortion resulting from overheating, which may weaken the container. Also, such flanges used for attaching components to the container may provide potential locations for leakage and/or freezing.

SUMMARY

In accordance with the present disclosure, fluid container apparatuses, and more particularly fluid container apparatuses having support elements for supporting, aligning, and/or securing apparatus components, may be provided.

In accordance with one embodiment of the present disclosure, a fluid storage and delivery apparatus includes a fluid container, a first apparatus component, and a housing. One or more support members may be coupled to the housing and configured to secure the first apparatus component physically separate from the fluid container. The first apparatus component may be indirectly coupled to the fluid container by one or more coupling members at least partially defining a fluid passageway between the first apparatus component and the fluid container.

In accordance with another embodiment of the present disclosure, a housing for a fluid storage and delivery apparatus includes a housing portion configured to at least partially house one or more components of the fluid storage and delivery apparatus. The housing also includes one or more support members coupled to the housing portion and configured to secure a first one of the components physically separate from a second one of the components. The first and second components may be indirectly coupled to each other by one or more coupling members at least partially defining a fluid passageway between the first and second components.

In accordance with yet another embodiment of the present disclosure, a fluid storage and delivery apparatus includes

means for storing a fluid, means for communicating at least a portion of the fluid to or from the fluid storage means, means for at least partially housing the fluid storage means and the fluid communication means, and means coupled to the housing for securing the fluid communication means physically separate from the fluid storage means. The fluid communication means may be indirectly coupled to the fluid storage means by one or more coupling members at least partially defining a fluid

BRIEF DESCRIPTION OF THE DRAWINGS

Some embodiments of the disclosure may be understood by referring, in part, to the following description and the accompanying drawings, in which like reference numbers refer to the same or like parts, and wherein:

FIG. **1** illustrates a fluid management apparatus according to one embodiment of the present disclosure;

FIG. **2** illustrates an example LOX apparatus having the rear housing removed to show various components of the LOX apparatus housed within front housing;

FIG. **3** illustrates the inside of the front housing of an example LOX apparatus according to one embodiment of the disclosure;

FIG. **4** illustrates the inside of the rear housing of an example LOX apparatus according to one embodiment of the disclosure;

FIG. **5** illustrates example fill port support members coupled to or formed in a front housing of an LOX apparatus, according to one embodiment of the disclosure;

FIG. **6** illustrates an example fill port secured within the fill port support members shown in FIG. **5**, according to one embodiment of the disclosure;

FIG. **7** illustrates example fill port support members coupled to or formed in a rear housing of an LOX apparatus, according to one embodiment of the disclosure;

FIG. **8** illustrates an example fill port secured within the fill port support members shown in FIG. **7**, according to one embodiment of the disclosure;

FIG. **9** illustrates example vent valve support members coupled to or formed in a front housing of an LOX apparatus, according to one embodiment of the disclosure;

FIG. **10** illustrates an example vent valve secured by vent valve support members formed in a front housing of an LOX apparatus, according to one embodiment of the disclosure;

FIG. **11** illustrates example relief/economizer valve support members coupled to or formed in a front housing of an LOX apparatus, according to one embodiment of the disclosure;

FIG. **12** illustrates an example fill port physically decoupled from a container in accordance with one embodiment of the disclosure;

FIG. **13** illustrates an example vent valve physically decoupled from a container in accordance with one embodiment of the disclosure;

FIG. **14** illustrates an example relief/economizer valve physically decoupled from a container in accordance with one embodiment of the disclosure;

FIGS. **15**A and **15**B illustrates an example fill port according to one embodiment of the present disclosure;

FIG. **16** illustrates an example prior art fill port;

FIG. **17** illustrates a side view of an example vent valve in a closed valve position, according to one embodiment of the present disclosure;

FIG. **18** illustrates a side view of an example vent valve in an open valve position, according to one embodiment of the present disclosure;

FIG. **19** illustrates a rear view of an example vent valve in a closed valve position, according to one embodiment of the present disclosure;

FIG. **20** illustrates a front view of an example vent valve in an open valve position, according to one embodiment of the present disclosure;

FIG. **21** illustrates an example control device of an LOX apparatus positioned in an off position, according to one embodiment of the present disclosure;

FIG. **22** illustrates an example control device of an LOX apparatus positioned in a continuous mode position, according to one embodiment of the present disclosure; and

FIG. **23** illustrates an example control device of an LOX apparatus positioned in a conserve mode position, according to one embodiment of the present disclosure.

DETAILED DESCRIPTION

Selected embodiments of the disclosure may be understood by reference, in part, to FIGS. **1-23**, wherein like number refer to same and like parts.

FIG. **1** illustrates a fluid management apparatus **10** according to one embodiment of the present disclosure. Fluid management apparatus **10** may be generally operable to provide and/or control the storage and/or delivery of one or more fluids, such as gasses and/or liquids, for example. In some embodiments, fluid management apparatus **10** may comprise a portable liquid oxygen (LOX) apparatus generally operable to store liquid oxygen and deliver gaseous oxygen (e.g., evaporated from the liquid oxygen) to a subject via one or more suitable gas passageways. The following discussion focuses on such LOX apparatuses **10**. However, it should be understood that in other embodiments, apparatus **10** may or not be portable, and may be used for storing and/or delivering any other fluid or fluids (instead of, or in addition to, oxygen).

The example LOX apparatus **10** shown in FIG. **1** may include a housing **12**, a container **14** (see, e.g., FIG. **2**), a fill port **16**, one or more outlets **18**, a control device **20**, and a vent valve **22** (see, e.g., FIG. **2**). Housing **12** may be configured to fully or partially house various components of apparatus **10**, such as container **14**, fill port **16**, vent valve **22**, outlets **18**, and/or control device **20**, for example. Housing **12** may include multiple portions that are coupled together in any suitable manner to form a housing around components of apparatus **10**. For example, housing **12** may include a front housing **24** and a rear housing **26** (see, e.g., FIGS. **3** and **4**) that couple together to form a shell or housing around components of apparatus **10**. In addition, in some embodiments, housing **12** may include support members **30** (see, e.g., FIGS. **3-11**) coupled to and/or formed on the inside of front housing **24** and/or rear housing **26**, which support members **30** may be generally configured to support, align, and/or secure one or more components of apparatus **10** in proper position.

Container **14** may be configured to receive, store, and/or deliver oxygen. Fill port **16** may be in fluid communication with container **14** and may be configured for filling container **14** with liquid oxygen, which filling may be referred to as "charging" container **14**. For example, fill port **16** may be configured to temporarily engage or connect to a LOX reservoir or some other source of LOX and facilitate the transfer of LOX from the LOX reservoir to container **14**.

Outlets **18** may be in fluid communication with container **14** and may be configured for delivering gaseous oxygen evaporated from the liquid oxygen in container **14** to a subject. For example, each outlet **18** may be configured to be attached to a hose, lumen, cannula or other passageway that may deliver the gaseous oxygen to the subject's breathing orifice(s) (e.g., nostrils).

Control device **20** may be configured for adjusting or controlling the operation of apparatus **10**. In some embodiments, control device **20** is configured to be manipulated by a user to adjust or control the operation of apparatus **10**. For example, control device **20** may include one or more knobs, dials, switches, buttons, or any other type of manipulatable devices. In certain embodiments, control device **20** may include a single device (e.g., a single dial, knob or switch) that allows a user to select from (a) multiple modes of oxygen flow and/or (b) multiple volumetric flow rates for the gaseous oxygen delivered by apparatus **10**. Example modes of oxygen flow may include (a) continuous mode and/or (b) conserve (or "demand") mode. Continuous mode may provide a steady, continuous flow of oxygen. Conserve mode may provide a regulated flow of oxygen, which may be regulated based on various inputs, such as physiological inputs from the subject. For example, in the conserve mode, the delivered oxygen flow may be reduced or interrupted during exhalation, which may reduce the amount of oxygen wasted during exhalation. In some embodiments, multiple different conserve modes may be provided, which may differ based on various parameters, such parameters regarding the detection of the subject's inhalation or attempted inhalation, for example. In certain embodiments, control device **20** may include a single device that allows a user to select both (a) between continuous mode and conserve mode and (b) the intensity or flow rate for the selected mode or a particular type or level of continuous or conserve mode.

FIG. **2** illustrates an apparatus **10** having the rear housing **26** removed to show various components of apparatus **10** housed within front housing **24**, according to one embodiment of the disclosure. For example, container **14**, fill port **16**, vent valve **22**, a regulator **44**, a relief/economizer valve **46**, and tubing **48** are indicated in FIG. **2**.

Vent valve **22** may allow a user to vent oxygen from container **14**, such as during the filling of container **14** or otherwise. Vent valve **22** may include a vent valve lever **49**, which may be actuated in order to open a valve allowing oxygen (liquid and/or gas) to vent from container **14**. For example, vent valve lever **49** may be actuated during the filling of container **14** to vent gaseous oxygen in order to release pressure in container **14**, thus allowing container **14** to be filled with LOX. In addition, the user may also identify when the container **14** is full of LOX when LOX begins exiting through vent valve **22**.

Regulator **44** may be generally operable to control the flow of gaseous oxygen being delivered by apparatus **10**, and may be controlled or adjusted by control device **20** or otherwise controlled or adjusted. For example, regulator **44** may be operable to control (a) the flow rate and/or (b) the mode of operation or gas delivery for the gaseous oxygen delivered by apparatus **10**. In some embodiments, regulator **44** may be operable to provide multiple modes of operation or gas delivery, such as (a) continuous mode and/or (b) conserve or demand mode, such as described above regarding control device **20**. In addition, regulator **44** may be able to provide multiple intensities, levels or settings for each of such operation or gas delivery modes. To provide such various options, in some embodiments, regulator **44** may include one or more valves, apertures of various shapes and/or sizes, and/or any other suitable components.

Relief/economizer valve **46** may be generally operable to regulate the pressure of oxygen within container **14**. For example, valve **46** may open to allow oxygen gas from a gaseous head-space in container **14** to pass through when the pressure of the oxygen gas in container **14** exceeds a predetermined threshold level, and may otherwise remain closed allowing oxygen gas from evaporated LOX to pass through.

It should be understood that apparatus **10** may also include any other components suitable for use in an LOX apparatus. For example, apparatus **10** may also include a heat exchanger, for example.

As discussed above, one or more components of apparatus **10** may be supported, aligned, and/or secured within housing **12** by one or more support members **30** coupled to or integrated with housing **12**. For example, one or more of container **14**, fill port **16**, vent valve **22**, regulator **44**, and/or relief/economizer valve **46** may be supported, aligned, and/or secured by one or more support members **30** coupled to or integrated with front housing **24** and/or rear housing **26**.

For example, as shown in FIGS. **3** and **4**, container **14** may be supported, aligned, and/or secured in place by one or more container support members **31**; fill port **16** may be supported, aligned, and/or secured in place by one or more fill port support members **32**; vent valve **22** may be supported, aligned, and/or secured in place by one or more vent valve support members **33**; regulator **44** may be supported, aligned, and/or secured in place by one or more regulator support members **35**; and relief/economizer valve **46** may be supported, aligned, and/or secured in place by one or more relief/economizer valve support members **36**.

One, some or all of support members **30** may include one or more front support members **30***a* coupled to or integrated with front housing **24** and/or one or more rear support members **30***b* coupled to or integrated with rear housing **26**, as shown and discussed below with respect to FIGS. **3** and **4**. In some embodiments, one or more front support members **30***a* may be configured to cooperate with one or more corresponding rear support members **30***b* to support, align, and/or secure one or more components in place. For example, front support members **30***a* may cooperate with rear support members **30***b* to provide support to one or more components of apparatus **10** such that forces acting upon such components do not damage such components or other components of apparatus **10**, whether during the filling of container **14**, during the operation of apparatus **10**, or otherwise.

Support members **30** may include any members or elements configured to help support, align, and/or secure a component in place. Support members **30** may have any shape, size, and orientation. For example, one or more generally straight support members **30** may be oriented horizontally, vertically, or at any other angle in any dimension. In some embodiments, one or more support members **30** may comprise ribs, brackets, clips, or may have any other shape or configuration. As discussed above, support members **30** may be coupled to or integrated with housing **12** in any suitable manner. For example, in some embodiments, one or more support members **30** may be formed integrally with housing **12** (e.g., front housing **24** and/or rear housing **26**), such as by molding or casting, for example. In other embodiments, one or more support members **30** may be coupled to housing **12** (e.g., front housing **24** and/or rear housing **26**) in any suitable manner, such as by adhesive, weld, braze, clipping, snapping, or using one or more mechanical fasteners, for example. In addition, support members **30** may be formed from any suitable material, such as plastic, metal, or composite, for example.

In some embodiments, the support members **30** for housing particular components may include multiple portions having different shapes, sizes or contours configured to receive different portions of such particular components. One or more support members **30** may be shaped, sized, and/or contoured to correspond with the shape, size, and/or contours of the corresponding component(s) of apparatus **10**. For example, as discussed below with reference to FIG. **5**, fill port support members **32** may include multiple portions having different shapes and/or contours configured to receive the different shapes and/or contours of different portions or components of fill port **16**.

FIG. **3** illustrates the inside of a front housing **24** of an example LOX apparatus **10**, according to one embodiment of the disclosure. As discussed above, apparatus **10** may include one or more front support members **30***a* coupled to or integrated with front housing **24**. In this embodiment, front support members **30***a* may include container support members **31***a*, fill port support members **32***a*, vent valve support members **33***a*, regulator support members **34***a*, and/or relief/economizer valve support members **35***a*.

FIG. **4** illustrates the inside of a rear housing **26** of an example LOX apparatus **10**, according to one embodiment of the disclosure. As discussed above, apparatus **10** may include one or more rear support members **30***b* coupled to or integrated with rear housing **26**. In this embodiment, rear support members **30***b* may include container support members **31***b*, fill port support members **32***b*, regulator support members **34***b*, and/or relief/economizer valve support members **35***b*.

Container support members **31***a* and **31***b* may be configured to cooperate to support, align, and/or secure container **14** in place; fill port support members **32***a* and **32***b* may be configured to cooperate to support, align, and/or secure fill port **16** in place; vent valve support members **33***a* may be configured to support, align, and/or secure vent valve **22** in place, regulator support members **34***a* and **34***b* may be configured to cooperate to support, align, and/or secure regulator **44** in place, and relief/economizer valve support members **35***a* and **35***b* may be configured to cooperate to support, align, and/or secure relief/economizer valve **46** in place.

One or more support members **30***a* and/or **30***b* may be shaped and/or sized to mate with or receive the corresponding component(s) of apparatus **10**. For example, as shown in FIG. **3** (and more clearly shown in FIG. **5**), particular fill port support members **32***a* may be V-shaped to receive a V-shaped portion of fill port **16**. As another example, as shown in FIG. **9** and discussed below, vent valve support members **33***a* may include tubular openings **50** shaped, sized, and/or aligned to receive alignment pegs **52** (shown in FIGS. **17-19**) extending from vent valve **22** in order to properly align vent valve **22** relative to front support members **33***a*. In addition, one or more support members **30***a* and/or **30***b* may be configured to receive mechanical fasteners, such as screws, bolts, or clips, for example. For instance, as shown in FIG. **3**, vent valve support members **33***a* may form a screw hole **54** configured to receive a screw **56** (see FIG. **10**) for securing vent valve **22** to front housing **24**.

Some or all of support members **30***a* and/or **30***b* may provide one, some or all of the following functions or advantages. First, one or more of support members **30***a* and/or **30***b* may support, align, and/or secure particular components within housing **12** as desired. This may ensure the proper alignment of particular components and/or increase the overall stability and strength of apparatus **10**. Second, one or more of support members **30***a* and/or **30***b* may physically decouple particular components of apparatus **10** from each other. For example, as shown in FIG. **2**, one or more of support members **30***a* and/or **30***b* may be configured to physically decouple fill port **16**, vent valve **22**, regulator **44**, relief/economizer valve **46**, and/or any other component from container **14**, such that one or more of such components are not directly coupled to container **14**. Thus, for example, as shown in FIG. **2**, one or more of such components may be coupled to container **14** via tubing rather than being directly coupled to container **14**, such as by a weld, braze, flange, or mechanical fastener (e.g., a worm-drive clamp or nut-and-bolt).

Physically decoupling components (e.g., fill port **16**, vent valve **22**, regulator **44**, and/or relief/economizer valve **46**) from container **14** may provide one or more advantages. For example, physically decoupling a component from container **14** may reduce or substantially eliminate the extent to which such stresses and strains experienced by that component (e.g., during filling of container **14**, during operation of apparatus **10**, or otherwise) are transferred to container **14**, which may reduce the likelihood of container **14** being undesirably stressed or strained, or being punctured, cracked, or otherwise damaged.

In addition, securing components in place using support members **30** may reduce the extent to which such components may move (e.g., laterally in one or more directions and/or rotationally) relative to each other (e.g., relative to container **14**), which may also reduce or substantially eliminate the extent to which such stresses and strains experienced by various components are transferred to each other (e.g., to container **14**). Thus, the likelihood of stresses and strains on one component being undesirably transferred to another component (e.g., to container **14**) may be reduced or substantially eliminated.

In addition, in some embodiments, physically decoupling components from each other using support members **30** may reduce or substantially eliminate damage caused to heat-sensitive components from high-temperature manufacturing techniques, such as welding or brazing, for example. Heat generated by such high-temperature manufacturing techniques may thus be localized, which may reduce the likelihood of heat-sensitive components physically decoupled from the area of a high-temperature process being damaged during such process.

The location of fill port support members **32***a* and/or **32***b* may ensure that fill port **16** is properly aligned with an opening **58** in front housing **24** and rear housing **26** (see FIGS. **3** and **4**) such that a user may properly fill container **14** with LOX. Additionally, when front housing **24** and rear housing **26** are coupled, fill port front support members **32***a* may engages fill port rear support members **32***b* to provide a complete or near-complete 360-degree range of structural support for fill port **16**. Such structural support may be particularly useful when fill port **16** is engaged with an external source of LOX, such as during the filling of container **14**. During the filling of container **14**, fill port **16** may experience various stresses and strains. As discussed above, decoupling fill port **16** from container **14** using support members **32***a* and/or **32***b* may reduce or substantially eliminate the extent to which such stresses and strains experienced by fill port **16** (whether associated with filling container **14** or otherwise) are transferred to container **14**. In addition, securing fill port **16** in place using fill port support members **32***a* and/or **32***b* may reduce the extent to which fill port **16** may move (e.g., laterally in one or more directions and/or rotationally) relative to container **14**, which may also reduce or substantially eliminate the extent to which such stresses and strains experienced by fill port **16** are transferred to container **14**. Thus, the likelihood of stresses and strains on fill port **16** causing fill port **16** to break away from or puncture container **14**, or otherwise form cracks or leaks in apparatus **10**, may be reduced or substantially eliminated.

Vent valve support members **33***a* may be configured to receive the contours of vent valve **22** to properly align, support, and/or secure vent valve **22**. As discussed above, vent valve support members **33***a* may incorporate a mechanical connection to help secure vent valve **22** to front housing **24**, e.g., a screw, bolt, or other fastener, for example. In other embodiments, one or more vent valve support members **33** may be coupled to or integrated with rear housing **26**, and may cooperate with vent valve support members **33***a* coupled to or integrated with front housing **24** in order to support, align, and/or secure vent valve **22**.

As discussed above, container support members **31***a* and/or **31***b* coupled to and/or integrated with front housing **24** and/or rear housing **26** may support, align and/or secure container **14**. This may reduce movement of container **14** (e.g., laterally in one or more directions and/or rotationally), which may in turn reduce vibrational noise.

FIG. **5** illustrates example fill port support members **32***a* coupled to or formed in front housing **24** of apparatus **10**, according to one embodiment of the disclosure. In some embodiments, fill port support members **32***a* may include multiple portions **72***a*, **74***a*, and **76***a* having different shapes and/or contours configured to receive the different shapes and/or contours of different portions or components of fill port **16**. In this example embodiment, portion **76***a* may include generally V-shaped ribs **78** configured to receive a V-shaped portion of fill port **16**.

FIG. **6** illustrates an example fill port **16** secured within fill port support members **32***a* shown in FIG. **5**, according to one embodiment of the disclosure. Different shaped and/or contoured portions **80**, **82**, and **84** of fill port **16** may be received within portions **72***a*, **74***a*, and **76***a* of fill port support members **32***a* (shown in FIG. **5**).

FIG. **7** illustrates example fill port support members **32***b* coupled to or formed in rear housing **26** of apparatus **10**, according to one embodiment of the disclosure. As discussed above, fill port support members **32***b* may cooperate with fill port support members **32***a* formed in front housing **24** in order to secure fill port **16** in position. Like fill port support members **32***a*, fill port support members **32***b* may include multiple portions **72***b*, **74***b*, and **76***b* having different shapes and/or contours configured to receive the different shapes and/or contours of different portions or components of fill port **16**.

FIG. **8** illustrates an example fill port **16** secured within fill port support members **32***b* shown in FIG. **7**, according to one embodiment of the disclosure. Other components of apparatus **10**, such as container **14**, have been removed for illustrative purposes. Different shaped and/or contoured portions **80**, **82**, and **84** may be received within portions **72***b*, **74***b*, and **76***b* of fill port support members **32***b* (shown in FIG. **7**).

FIG. **9** illustrates example vent valve support members **33***a* coupled to or formed in front housing **24** of apparatus **10**, according to one embodiment of the disclosure. As discussed above, in some embodiments, vent valve support members **33***a* may include one or more tubular openings **50** shaped, sized, and/or aligned to receive alignment pegs **52** (see FIGS. **17-19**) extending from vent valve **22** in order to properly align vent valve **22** relative to front support members **33***a*. In addition, vent valve support members **33***a* may form a screw hole **54** configured to receive a screw **56** to secure vent valve **22** in place.

FIG. **10** illustrates an example vent valve **22** secured by vent valve support members **33***a* formed in front housing **24**, according to one embodiment of the disclosure. Other components of apparatus **10**, such as container **14**, have been removed for illustrative purposes only. Pegs **52** extending from vent valve **22** may be positioned in openings **50**, and a screw **56** may be screwed into screw hole **54** to secure vent valve **22**. Vent valve lever **49** may extend through a lever opening **90** formed in rear housing **26** such that lever **49** may be easily accessed by a user.

FIG. **11** illustrates example relief/economizer valve support members **35***a* coupled to or formed in front housing **24** of apparatus **10**, according to one embodiment of the disclosure. Relief/economizer valve support members **35***a* may cooperate with relief/economizer valve support members **35***b* coupled to or formed in rear housing **26** to support, align, and or secure relief/economizer valve **46** in position.

As discussed above, one or more of support members **30***a* and/or **30***b* may physically decouple particular components of apparatus **10** from each other, which may provide various advantages, such as decreasing the likelihood of container **14** becoming cracked or punctured due to various stresses and strains, for example. As discussed below, FIGS. **12-14** illustrate such decoupling of fill port **16**, vent valve **22**, and relief/economizer valve **46** from container **14**.

FIG. **12** illustrates fill port **16** physically decoupled from container **14** in accordance with one embodiment of the disclosure. In this embodiment, fill port support members **32** secure fill port **16** physically separate from container **14**, and fill port **16** is connected to container **14** by tubing **48***a*. Tubing **48***a* may be coupled to an adaptor **102** of fill port **16** and/or to container **14** in any suitable manner, such as by weld, braze, or mechanical fastener, for example. The shape and/or configuration of tubing **48***a* may provide some flexibility and/or dampening such that the transfer of stresses or strains from fill port **16** to container **14** may be reduced or substantially eliminated, as compared to a configuration in which fill port **16** is directly coupled to container **14**.

Decoupling fill port **16** from container **14** may be advantageous, for example, when fill port **16** is engaged with an external source of LOX, such as during the filling of container **14**. As discussed above, decoupling fill port **16** from container **14** using support members **32** may reduce or substantially eliminate the extent to which such stresses and strains experienced by fill port **16** (whether associated with filling container **14** or otherwise) are transferred to container **14**. Thus, the likelihood of stresses and strains on fill port **16** causing fill port **16** to break away from or puncture container **14**, or otherwise form cracks or leaks in apparatus **10**, may be reduced or substantially eliminated.

FIG. **13** illustrates vent valve **22** physically decoupled from container **14** in accordance with one embodiment of the disclosure. In this embodiment, vent valve support members **33** secure vent valve **22** physically separate from container **14**, and vent valve **22** is connected to container **14** by tubing **48***b*. Tubing **48***b* may be coupled to an inlet **132** of vent valve **22** and to container **14** in any suitable manner, such as by weld, braze, or mechanical fastener. For example, in this embodiment, inlet **132** may be threaded to receive a ferrule nut **133** for securing tubing **48***b* to inlet **132**. Such configuration may reduce the complexity and/or number of parts needed to connect inlet **132** to container **14**.

The shape and/or configuration of tubing **48***b* may provide some flexibility and/or dampening such that the transfer of stresses or strains from vent valve **22** to container **14** may be reduced or substantially eliminated, as compared to a configuration in which vent valve **22** is directly coupled to container **14**. Thus, for example, stresses and strains experienced by vent valve **22** due to actuation of vent valve lever **49** (e.g., during filling or otherwise) may not be transferred to container **14**, as compared to a configuration in which vent valve **22** is directly coupled to container **14**.

Also, in some embodiments, no flange is needed to mechanically connect vent valve **22** to container **14**. The elimination of a flange may reduce the number of parts required for vent valve **22**, the possibility of a leak or freezing, and/or the likelihood of container **14** being punctured (e.g., during filling or otherwise).

In addition, by physically decoupling vent valve **22** from container **14**, heat generated by various high-temperature coupling techniques (e.g., welds or brazes) may be localized, which may reduce the likelihood of heat-sensitive components being damaged during such high-temperature coupling techniques. For example, in some embodiments, vent valve **22** may include one or more seals or other heat-sensitive components that may be damaged by exposure to high-temperatures. In such embodiments, high-temperature coupling techniques may be performed to couple tubing **48***b* to container **14** without damaging such heat-sensitive components due to the fact that such heat-sensitive components are physically displaced from container **14**.

FIG. **14** illustrates relief/economizer valve **46** physically decoupled from container **14** in accordance with one embodiment of the disclosure. In this embodiment, relief/economizer valve support members **35** may secure relief/economizer valve **46** physically separate from container **14**, and relief/economizer valve **46** may be connected to container **14** by tubing **48***c*. Tubing **48***c* may be coupled to relief/economizer valve **46** and container **14** in any suitable manner, such as by weld, braze, or mechanical fastener. The shape and/or configuration of tubing **48***c* may provide some flexibility and/or dampening such that the transfer of stresses or strains from relief/economizer valve **46** to container **14** may be reduced or substantially eliminated, as compared to a configuration in which relief/economizer valve **46** is directly coupled to container **14**.

FIGS. **15**A and **15**B illustrate an example fill port **16** according to one embodiment of the present disclosure. Fill port **16** may include a female fill connector assembly **100**, and an adapter **102**. Female fill connector assembly **100** may include a body portion **104** and a female sleeve connector portion **106**. As discussed above, fill port **16** may be physically decoupled from container **14**. For example, as shown in FIG. **12**, adapter **102** may be coupled to container **14** via tubing **48***a*. Tubing **48***a* may be coupled to adapter **102** in any suitable manner, such as by welding, brazing, or using a mechanical fastener, for example. In contrast to certain prior art LOS apparatuses, fill port **16** of apparatus **10** may be secured by support members **30** rather than being coupled to container **14** by a flange or mechanical fastener. An example prior art fill port **16***a* is shown in FIG. **16**. The prior art fill port **16***a* may include a female fill connector assembly **100***a*, an adaptor **102***a*, and one or more connection components and/or fasteners for connecting fill port **16***a* directly to the LOX container. For example, as shown in FIG. **16**, such connection components and/or fasteners may include jam nut **112***a*, a ferrule nut **114***a*, and a compression sleeve **116***a*.

Thus, in embodiments of the present disclosure in which fill port **16** is not connected to container **14** via a flange, fill port **16** may not require such connection components and/or fasteners, such as jam nut **112***a*, ferrule nut **114***a*, compression sleeve **116***a*, and/or other fastener(s) to attach fill port **16** to such flange. Thus, fill port **16** may include fewer parts than prior fill ports, which may reduce the complexity and/or weight of LOX apparatus **10**. In addition, the elimination of such connection components and/or fasteners (e.g., jam nut **112***a*, ferrule nut **114***a*, and/or compression sleeve **116***a*) to attach fill port **16** to a flange may remove another potential source of leakage and/or freezing.

FIGS. **17**-**20** illustrate an example vent valve **22** in accordance with one embodiment of the present disclosure. In particular, FIG. **17** illustrates a side view of vent valve **22** in a closed valve position; FIG. **18** illustrates a side view of vent valve **22** in an open valve position; FIG. **19** illustrates a rear view of vent valve **22** in a closed position; and FIG. **20** illustrates a front view of vent valve **22** in an position.

Vent valve **22** may include a valve body **130**, an inlet **132**, an outlet **134**, a valve lever **49**, and/or a plunger **136** (see FIG. **20**). In general, inlet **132** and outlet **134** may be connected by a passageway that may be closed (or blocked) or opened (or at least partially unblocked) based on the positioning of plunger **136** within an opening formed within valve body **130**. Plunger **136** may be coupled to valve lever **49** such that actuation of valve lever **49** (e.g., manual actuation by a user) may pull plunger **136** downward from a closed position (see FIGS. **17** and **19**) in which the passageway connecting inlet **132** and outlet **134** is closed to an open position (see FIGS. **18** and **20**) in which the passageway connecting inlet **132** and outlet **134** is opened. Plunger **136** may include one or more sealing members configured to provide a suitable seal within valve body **130**.

In some embodiments, valve body **130** may comprise a single integrated piece. This may be advantageous as compared to prior art valve bodies having multiple pieces joined together, as the joints between such multiple pieces may provide a potential source of leakage and/or freezing. In addition, in some embodiments, using a single-piece, integrated valve body **130** may eliminate the need for a seal or seals (such as an O-ring, for example) which may be included in prior valve bodies having multiple pieces. Thus, another source of leakage and/or freezing may be eliminated. In addition, vent valve **22** may include fewer parts than vent valves, which may reduce the complexity and/or weight of LOX apparatus **10**.

In addition, one or both of inlet **132** and outlet **134** may be integral with valve body **130**. In this example embodiment, inlet **132** is integral with valve body **130**, whereas outlet **134** is separate and coupled to valve body **130**. In other embodiments, valve body **130** may be formed from multiple pieces and/or both inlet **132** and outlet **134** may be separately coupled to valve body **130**. As discussed above, valve body **130** may include one or more alignment pegs **52** used for aligning and/or securing vent valve **22** relative to housing **12**.

In some embodiments, inlet **132** and outlet **134** may be formed in the same general plane or in generally parallel planes. For example, an axis **140** defined by inlet **132** and an axis **142** defined by outlet **134** may reside in the same or generally parallel planes. This may provide various advantages, such as increased ease of manufacturing and/or assembly, which may improve product quality and/or reliability. In addition, configuring vent valve **22** as described herein and/or the use of support members **33** may reduce or eliminate the likelihood of vent valve **22** being misaligned during assembly or otherwise, which may also improve product quality and/or reliability.

As discussed above, fill port **16** may be physically decoupled from container **14**. For example, as shown in FIG. **13**, inlet **132** may be configured to be coupled to container **14** by tubing **48***b*, rather than being directly coupled to container **14**. The shape and configuration of tubing **48***b* may provide some flexibility and/or dampening such that the transfer of stresses or strains from vent valve **22** to container **14** may be reduced or substantially eliminated, as compared to a configuration in which vent valve **22** is directly coupled to container **14**. Tubing **48***b* may be coupled to inlet **132** in any suitable manner, such as by weld, braze, or mechanical fastener. For example, in this embodiment, inlet **132** may be threaded to receive a ferrule nut to secure tubing **48***b* to inlet

132. Such configuration may reduce the complexity and/or number of parts needed to connect inlet **132** to container **14**.

FIGS. **21-23** illustrate an example control device **20** for adjusting or controlling the flow of gaseous oxygen delivered by apparatus **10**, according to one embodiment of the disclosure. As discussed above, control device **20** may be configured to be manipulated by a user to adjust or control the flow of gaseous oxygen delivered by apparatus **10**. In this example, control device **20** comprises a single knob that allows a user to (a) select between at least three modes of operation: off, continuous mode, and conserve (or demand) mode, and (b) select the intensity, flow rate, level, or flow type for the selected mode. The various modes of operation and intensities (or flow rates) may be regulated by regulator **44**, such as discussed above with respect to FIG. **2**.

In the embodiment shown in FIGS. **21-23**, control device **20** comprises a single knob that may be rotated to select any of the following settings, each indicated on the knob using the following labels:

Knob label	Mode and/or intensity/flow rate/level
O	Off
C_1	Continuous mode, flow rate #1
C_2	Continuous mode, flow rate #2
C_3	Continuous mode, flow rate #3
C_4	Continuous mode, flow rate #4
C_5	Continuous mode, flow rate #5
C_6	Continuous mode, flow rate #6
$D_{1.5}$	Conserve mode #1
D_2	Conserve mode #2
$D_{2.5}$	Conserve mode #3
D_3	Conserve mode #4
D_4	Conserve mode #5

Thus, the user may easily—e.g., using a single knob—select between multiple modes and or intensities or flow rates as desired, which may be advantageous over apparatuses in which the user must manipulate multiple control devices to select such options.

FIG. **21** illustrates knob **20** positioned in the off position (labeled "O"). FIG. **22** illustrates knob **20** positioned in a particular continuous mode position (labeled "C_2"), after being rotated counter-clockwise from the off position, as indicated by arrow **150**. FIG. **23** illustrates knob **20** positioned in a particular continuous mode position (labeled "D_2"), after being rotated clockwise from the off position, as indicated by arrow **152**.

Although the disclosed embodiments have been described in detail, it should be understood that various changes, substitutions and alterations can be made herein without departing from the spirit and scope of the disclosure as illustrated by the following claims. For example, it should be understood that in various embodiments, apparatus **10** may include any combination of one, some or all of the various components and/or features discussed above and/or any one or more additional components and/or features.

What is claimed is:

1. A fluid storage and delivery apparatus, comprising:

a fluid container;

a vent valve; and

a housing including a first housing portion and a second housing portion, the first housing portion including one or more vent valve support ribs for supporting the vent valve;

wherein the second housing portion defines a vent valve opening; and

wherein a first portion of the vent valve is secured physically separate from the fluid container by the one or more vent valve support ribs and a second portion of the vent valve extends through the vent valve opening when the first and second housing portions are assembled together.

2. An apparatus according to claim **1**, wherein the fluid container is configured for storing liquid oxygen and delivering gaseous oxygen.

3. An apparatus according to claim **1**, further comprising:

a fill port for filling the fluid container;

the first housing portion further including one or more fill port support ribs for supporting the fill port;

wherein assembling the first and second housing portions together defines a fill port opening; and

wherein a first portion of the fill port is secured physically separate from the fluid container by the one or more fill port support ribs and a second portion of the fill port extends through the fill port opening defined by the assembled first and second housing portions.

4. An apparatus according to claim **3**, wherein:

the fill port includes a first portion having a first shape and a second portion having a second shape different from the first shape; and

the one or more fill port support ribs comprise at least one first rib shaped to receive the first portion of the fill port and at least one second rib shaped to receive the second portion of the fill port.

5. An apparatus according to claim **1**, further comprising:

an economizer valve for regulating the pressure of fluid within fluid container; and

one or more economizer valve support ribs coupled to the first housing portion for supporting the economizer valve.

6. An apparatus according to claim **1**, wherein the first housing portion further includes support ribs configured to secure a fill port and an economizer valve physically separate from the fluid container.

7. An apparatus according to claim **1**, wherein at least one of the vent valve support ribs is formed integrally with the housing.

8. An apparatus according to claim **1**, wherein at least one of the vent valve support ribs is shaped to match a contour of the vent valve.

9. An apparatus according to claim **1**, further comprising one or more coupling members at least partially defining a fluid passageway between the vent valve and the fluid container, wherein the one or more coupling members are flexible to provide dampening between the vent valve and the fluid container.

10. An apparatus according to claim **1**, wherein the second housing portion includes one or more second vent valve support ribs configured to cooperate with one or more first vent valve support ribs to secure the vent valve physically separate from the fluid container.

11. An apparatus according to claim **1**, wherein:

the second housing portion includes one or more vent valve support ribs for supporting the vent valve; and

wherein the first portion of the vent valve is secured physically separate from the fluid container by the one or more vent valve support ribs of the first housing portion and by the one or more vent valve support ribs of the second housing portion.

12. A housing for a fluid storage and delivery apparatus, comprising:

a first housing portion and a second housing portion configured, when assembled together, to at least partially house multiple components of the fluid storage and delivery apparatus;

one or more first support ribs coupled to the first housing portion; and

one or more second support ribs coupled to the second housing portion;

wherein assembling the first housing portion with the second housing portion defines an opening between the first and second housing portions, wherein a first one of the components extends through the opening; and

wherein the one or more first support ribs cooperate with the one or more second support ribs to secure the first component physically separate from a second one of the components, the first and second components being indirectly coupled to each other by one or more coupling members at least partially defining a fluid passageway between the first and second components.

13. A housing according to claim **12**, wherein the fluid storage and delivery apparatus comprises a liquid oxygen storage and delivery apparatus for storing liquid oxygen and delivering gaseous oxygen.

14. A housing according to claim **12**, wherein:

the second component comprises a container for storing a pressurized liquid;

the first component comprises a fill port for filling the container; and

the one or more coupling members comprise tubing for communicating liquid from the fill port into the container.

15. A housing according to claim **14**, wherein:

the fill port includes a first portion having a first shape and a second portion having a second shape different from the first shape; and

the one or more first support ribs comprise a first portion shaped to receive the first portion of the fill port and a second portion shaped to receive the second portion of the fill port.

16. A housing according to claim **12**, wherein the one or more support members are configured to secure a fill port, a vent valve, and an economizer valve physically separate from a fluid container.

17. A housing according to claim **12**, wherein at least one of the first support ribs is formed integrally with the first housing portion, and at least one of the second support ribs is formed integrally with the second housing portion.

18. A housing according to claim **12**, wherein at least one of the first support ribs is shaped to match a contour of the first component.

19. A housing according to claim **12**, wherein the one or more coupling members are flexible to provide dampening between the first component and the second component.

20. A fluid storage and delivery apparatus, comprising:

means for storing a fluid;

means for communicating at least a portion of the fluid to or from the fluid storage means; and

means for at least partially housing the fluid storage means and the fluid communication means, including a first housing means portion and a second housing means portion, the first housing means portion including one or more support ribs for supporting the fluid communication means;

wherein assembling the first and second housing means portions together defines an opening; and

wherein a first portion of the fluid communication means is secured physically separate from the fluid storage means at least by the one or more support ribs and a second portion of the fluid communication means extends through the opening defined by the assembled first and second housing means portions.

21. An apparatus according to claim **20**, wherein the fluid communication means comprises a fill port.

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